Bulletin 73 Mineral Technology 4

DEPARTMENT OF THE INTERIOR

FRANKLIN K. LANE, SECRETARY

BUREAU OF MINES

VAN. H. MANNING, DIRECTOR

BRASS-FURNACE PRACTICE

IN THE

UNITED STATES

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PREFACE.

In the preliminary investigations of the Bureau of Mines on the elimination of waste in our miscellaneous mineral industries, it early became apparent that there were big losses in the melting of the nonferrous alloys. In order to investigate this matter more fully, the cooperation of the American Institute of Metals and of the chemical department of Cornell University, Ithaca, N. Y., was enlisted. This cooperation was heartily given, and special acknowledgment is here made of the helpful enthusiasm and advice of Prof. W. D. Bancroft, and the interest shown by the members of the institute through whom a large part of the information presented in this bulletin was received.

The object of the investigation reported in this bulletin was to ascertain the melting and fuel losses in present brass-melting practice and to indicate, as far as possible, methods by which these losses might be reduced. Dr. H. W. Gillett, alloy chemist of the Bureau of Mines, was assigned to the investigation.

There are in America to-day some 3,600 plants melting brass and bronze, and 1,000 of these melt nonferrous alloys exclusively. The alloys of copper, zinc, tin, lead, or other elements in cast or wrought form play an important role in our daily life. Allowing for the present recovery of waste metal, it appears that in current practice, between the purchase of the raw metal and the completion of the finished product, at least 5 per cent of the original metal is lost. Zinc passes into the atmosphere through the furnace stack; the other metals in the alloy may be oxidized and pass into the stack, may be spilled in the furnace ashes, or in one way or another may not be completely recovered.

In the melting of nonferrous alloys, taking into consideration all such alloys and all furnaces and fuels used, it is shown that from 90 to 95 per cent of the heat units in the fuel do no useful work. On the basis of $120,000,000 being the value of the metal passing through brass and bronze furnaces each year, a 2½ per cent melting loss, equivalent to 5 per cent loss on metal bought, means an annual loss of $3,000,000 in metal alone. Simply reducing the average metal loss to that of present best practice would mean a saving of over $1,500,000 a year. If fuel efficiency and crucible life could be brought from present average to best practice, half million dollars more, at least, could be saved.

One of the most striking facts to which attention is called by this investigation is the lack of proper control and of proper records in most of our furnace practice. Of the 1,650 plants to which Dr. Gillett sent the list of questions, only 230 sent any data and about 50 of these stated that no records were kept. Few of the plants that replied are under technical control, and it may be fairly assumed that the figures given in this bulletin represent the best practice in the United States. Dr. Gillett has concluded that it is doubtful if there are 50 firms in the country that have daily furnace records that are exact enough to allow the correction of avoidable losses. The firms that keep proper records, and hence have the necessary knowledge, invariably employ a trained metallurgist to supervise the melting furnaces, and these firms almost always have the lowest losses. That there is wide lack of technical control is emphasized by reports of metal losses varying from one-tenth of 1 per cent to 22 per cent and fuel efficiency from 1½ per cent to 16 per cent. The need for thorough technical control in the majority of our foundries and casting shops has been made evident by this investigation.

Another waste not so readily expressed by figures but which none the less really exists is the loss of efficiency of the workers in the industry through occupational disease and accidents due to a lack of safety precautions. A few of the firms reporting have given careful consideration to the prevention of disease and accidents, and it is shown that by the enforcement of simple, proper precautions occupational disease may be eliminated and the nonferrous alloy industry placed beyond reproach as to the health and safety of its employees.

Investigation has also magnified the need of an efficient electric melting furnace in the alloy industry and a pyrometer which can be used as a workman's tool. These two problems are now under investigation by the Bureau of Mines.

Another point that the work has particularly developed is the need of special studies of the absorption of gases, the speed of melting, the effect of oxidizing or reducing flames, increase of crucible life, decrease of time of heating after melting, the efficiency of furnace linings, the utilization of waste heat, the strength of draft, the combustion space of furnaces, and the saving of metal from waste material.

The important plants engaged in the nonferrous alloy industry opened their doors freely to the employees of the Bureau of Mines during the progress of the investigation, and the written data furnished were supplemented by personal visits which Dr. Gillett made to 80 foundries and rolling mills, in 13 States. Information was given freely, and it is hoped that the results of the investigation will be of much value to the whole industry.

Charles L. Parsons,
Chief Division of Mineral Technology.

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By H. W. Gillett.

INTRODUCTION.

This bulletin is issued by the Bureau of Mines as a contribution to the increase of safety and efficiency in the preparation and utilization of the mineral resources in the United States. Notable among the drains on these resources are the demands made by the nonferrous-metal industries, and in these the losses occasioned in melting brass and bronze are worthy of particular attention. This statement will be better appreciated by a consideration of the size of the brass industry.

MAGNITUDE OF THE BRASS INDUSTRY.

According to the Thirteenth Census, in 1909 there were in the United States 1,021 firms that dealt mainly in brass and bronze. This total included jobbing foundries, manufacturing plants that both cast and machine a brass or bronze product, and rolling mills, but did not include iron foundries having nonferrous departments nor the numerous large brass-foundry departments of manufacturing plants that produce the castings used in the manufacture of electrical apparatus, cash registers, pumps, and the thousands of machines that require brass castings for their construction. Penton's Foundry List for 1910 gives about 1,150 exclusively nonferrous foundries and about 2,300 iron or steel foundries that also melt brass. If the rolling mills and jobbing foundries in manufacturing plants be included, and if due credit be given to the rapid growth of the industry in the last few years, largely through the stimulation of the automobile business, it is probable that not less than 3,600 plants are to-day melting brass or bronze.

The plants vary in size from the small shop using only one small furnace and employing only one or two molders to vast concerns melting ten, twenty, or even fifty million pounds of copper alloys a year. The alloys employed and their uses are legion, and the castings produced vary from tiny pieces weighing only a fraction of an ounce, such as buckles, up to huge 10-ton propellers for ocean liners.

LOSSES OF METAL AND FUEL IN MELTING BRASS AND BRONZE.

The losses, both of metal and fuel, in melting brass and bronze bulk large. The net loss of metal, if all recovery of any sort be deducted and if all the brass and bronze alloys be included, will average not less than 2.5 per cent. Extreme figures reported are 22 and 0.1 per cent, the former figure being unusual and not representing regular practice and the latter not being verified. Extremes of 8 and 0.5 per cent are well substantiated. The total melt will average about twice the raw metal bought, because of the remelt of crop ends and scrap in rolling mills and of gates and sprues in foundries. Some foundries making light castings melt 3 pounds of metal to get 1 pound of castings. A ratio of 2 pounds of metal to 1 pound of castings is common,[a] and 1½ to 1 is low. If, then, the whole industry be considered, a loss of 2.5 per cent on the gross melt is equal to about 5 per cent on the raw metal bought.

For the heat actually used in melting and bringing the metal up to an average pouring temperature, 140 kilogram-calories per kilogram (260 British thermal units per pound, or 26,000 British thermal units per hundredweight) of ordinary red brass is a liberal estimate,[b] and yellow brass requires less.

The following figures for heating values of the fuels ordinarily used in the foundry may be taken as close enough for purposes of calculation:

Heating values of fuels used in the foundry.

		British thermal units.
Coke, anthracite coal, bituminous coal	per pound	13,000
Fuel oil	do	[c] 19,000
Natural gas	per cubic foot	1,000
City gas	do	625
Producer gas	do	120

On this basis, if all the heat units in the fuel could be utilized in heating the metal, no deductions being made for the presence of water vapor in the products of combustion (using the "high" heating value), that is, with 100 per cent theoretical efficiency, it would take to heat 1 hundredweight of brass to a pouring temperature: Two pounds of coke or coal; 1.4 pounds, or 0.18 gallons, of oil; 26 cubic feet of natural gas; 41.5 cubic feet of city gas; 217 cubic feet of producer gas.

The limits representing actual practice, as reported in replies to inquiries incident to the investigation here outlined, are as follows:

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[a] Blair, P. W., Relation of metal cast to floor area of foundry: Metal Ind., vol. 11, 1913, p. 112.

[b] Richards, J. W., Electric power required to melt metals: Trans. Am. Brass Founders' Assn., vol. 4, 1910, p. 99. Hansen, C. A., Electric melting of copper and brass: Trans. Am. Inst. Met., vol. 6, 1912, p. 112.

[c] Or 145,000 British thermal units per gallon.

Quantities of different fuels required to heat 1 hundredweight of brass to pouring temperature.

Reply No.	Fuel.	Type of furnace.	Fuel required per hundredweight.	Percentage of theoretical heating value.
			Pounds.	
26	Coke	Forced-draft tilting	13	15½
133	.....do	Natural-draft pit	133	1½
21	Anthracite coal	.....do	25	12½
115	.....do	Forced-draft pit	125	1⅗
180	Bituminous coal.	Forced-draft reverberatory	18	11
202	.....do	.....do	88	2¼
			Gallons.	
79	Oil	Reverberatory	1.11	16
150	.....do	Square-pit	7.8	2½
			Cubic feet.	
104	Natural gas	Open-flame	200	13
145	.....do	Tilting crucible	480	7½
108	City gas	Pit	256	16
12	.....do	.....do	650	6½
164	Producer gas	.....do	3,500	6

Reply 154 (p. 104) reported the use of 7.5 pounds of coke per hundredweight in a forced-draft, tilting furnace, or 26 per cent efficiency. This figure is doubtful, although some makers of that type of furnace claim that it needs only 6 pounds of fuel per hundredweight, an efficiency of 33 per cent of the theoretical. The lowest fuel consumption reported [a] for a natural-draft, pit furnace using coal or coke was 20 pounds per hundredweight, or an efficiency of 10 per cent of the theoretical. For the oil furnaces figures were given very slightly above and below those noted above, but they could not be verified.

The fuel efficiency is therefore seen to vary between 1½ and 16 per cent, the average being 4 to 9 per cent. If all fuels and all furnaces be considered, it is doubtful whether the average fuel efficiency is more than 7 per cent of the theoretical.

MONETARY VALUE OF THE LOSSES.

In 1909, according to the Thirteenth Census, [b] 1,021 establishments making brass and bronze products spent for materials $99,228,000. If it be assumed that 80 per cent of that amount was for metal, $80,000,000 is spent annually for raw metals in such establishments, which do not comprise a third of the whole number of firms that melt brass and bronze.

No attempt was made to procure data on the tonnage melted, but 10 firms—manufacturers of commodities listed under other headings in the census reports—did give such data, the total being 58,000,000 pounds for the 10 firms, some of which are not exceptionally large. If a ratio of melt to metal bought of 2 to 1 be allowed, the figures

[a] Reply 163. [b] Thirteenth Census, Advance Bulletin, Statistics of Manufacturers, 1910, p. 75.

quoted mean that 29,000,000 pounds of metal was bought at a value of about \$4,000,000. In view of the known size of other firms, not included in the Census classification under manufacturers of brass and bronze products but furnishing replies to inquiries, a conservative estimate of the value of the metal bought by such firms would be about six times that bought by the 10 firms mentioned, or, say, \$24,000,000, which, with the \$80,000,000 for those that are included, makes \$104,000,000 spent for metal by the firms included in the Census statistics and by those furnishing replies. As many other firms melting brass and bronze do not fall into either of these classes, it appears that the estimated value of all the metal used should be at least \$120,000,000.

The consumption of copper in the United States in 1911 was about 680,000,000 pounds.[a] If two-thirds of this total, or 450,000,000 pounds, be considered as having been used for making brass and bronze, and if the average copper content of the alloys used be assumed as 80 per cent, the deduction would be that about 560,000,000 pounds of brass and bronze products was made from new copper. It seems conservative to estimate that at least two-thirds of the copper consumed in the country is in the form of brass and bronze, as Lathrop[b] states that one corporation making mainly wrought yellow brass uses in its various plants approximately a third of all the copper consumed in the United States. To this must be added the old metal used. Half as much old scrap or alloyed ingot as new metal, that is, 280,000,000 pounds,[c] seems a fair estimate, so that 840,000,000 pounds should represent the total metal bought. The average value of brass and bronze being taken at 15 cents a pound, by this method of figuring \$126,000,000 would be the value of the metal passing through the brass and bronze furnaces of the United States in a year. For purposes of computation the estimate of \$120,000,000 has been taken.

A $2\frac{1}{2}$ per cent melting loss, equivalent to a loss of 5 per cent on the metal bought, thus means \$3,000,000 a year lost in metal alone. Could this be reduced to the $2\frac{1}{2}$ per cent loss (equivalent to $1\frac{1}{4}$ per cent on the melt) shown by good practice, a saving of \$1,500,000 a year would result. If the fuel consumption and crucible life were brought from the average practice up to good practice, and if furnaces that cut down or eliminate crucible cost and allow greater production with less labor cost were used wherever practicable, a saving of at least another half million would be made, or a total of \$2,000,000 a year that the nonferrous-alloy industry of the United States might

[a] Mineral Industry, 1911, p. 165.

[b] Lathrop, W. S., The brass industry of Connecticut, 1909, p. 127.

[c] U. S. Geological Survey Press Bull. 117, The country's enormous junk heap, June, 1913, p. 2. The recovery of secondary copper by smelters and refiners in 1912 is here given as 137,507 tons. This figure is on copper and the copper content of the recovered brass. That for remelted brass (alloyed ingot) is 101,437 tons, or nearly 203,000,000 pounds. Besides this, in foundries themselves there is a large remelt of old scrap, which does not reach the refiner. See also Foundry, vol. 41, 1913, p. 384.

save merely by bringing average furnace practice up to the standard of the best practice.

However it be figured, it is certain that the statement that the problem of the wastes in brass melting is one of the greatest importance in the conservation of waste in alloy manufacture[a] is correct.

OBJECT AND METHOD OF THE INVESTIGATION.

The object of the investigation here reported was to find out the melting and fuel losses in brass melting as practiced at present, and to indicate, as far as possible, the methods by which the losses may be reduced. To this end endeavor was made to collect data from as many plants melting brass as were willing to cooperate. Such data should serve not only to show the melter of brass what others are doing, and to allow him to compare his own work with the practice of others, but also to show on what points further invention and improvements are needed, and thus serve as a guide in planning further investigations by the bureau.

The cooperation of the American Institute of Metals was enlisted, and a large part of the information here recorded has been received from the members of that institute.

METHODS OF COLLECTING DATA.

A list of questions was sent to all members of the institute and to brass foundries and rolling mills in general. Questions were sent to every plant whose main business was known to be the production of brass, bronze, or similar alloys. The questions were sent also to all manufacturing plants known to melt these alloys in any considerable amount, to such iron foundries as were known to melt a large enough tonnage of copper alloys to make it likely that the data desired were recorded by them, and to all the iron foundries in Penton's list the firm name of which mentioned brass or bronze.

In all about 2,000 lists of questions were thus sent out. The questions asked were as follows:

DATA ON MELTING FURNACES.

[Cooperative investigations of the Bureau of Mines and the American Institute of Metals.]

Please answer fully the following questions, making separate lists of answers for each type of furnace with which you have had experience. The basis for the figures is a working day for one furnace, as this can probably be most easily obtained from existing records.

1. What is the type of furnace (pit, tilting with crucible, tilting without crucible, electric) used? Maker's name.
2. Shape and dimensions of furnace.
3. Lining—material, thickness.
4. Cover—shape, size, and material.
5. Size crucible used.
6. What fuel used?

[a] Parsons, C. L., Notes on mineral wastes: Bull. 47, Bureau of Mines, 1912, p. 20.

7. Details of fuel and air supply.

(a) For coal and coke furnaces—give grade of fuel used; also analyses and British thermal units per pound, if possible; what vacuum, if natural draft; what pressure, if forced draft.

(b) For gas—state whether natural gas or artificial; British thermal units per cubic foot, if possible; pressure of gas at burner; pressure of air at burner; type of burner.

(c) For oil—give specific gravity, or degrees Baumé, and temperature at which density was determined; British thermal units per gallon, if possible; pressure of oil at burner; pressure of air at burner; type of burner.

(d) For electricity—give voltage and amperage taken by furnace, and other details, as power factor of furnace, etc.

8. Number of furnaces one furnace tender can handle.

(Answer questions 8 to 19 on basis of red brass.)

9. Amount of fuel used per furnace per day—pounds of coal or coke, gallons of oil, cubic feet of gas, kilowatt-hours of electricity.

10. Number of heats per working day.

11. Hours per working day of furnace—from time cold furnace is started till day is over.

12. How often are furnaces relined, or other repairs made?

13. How many heats to the life of a crucible?

14. Total pounds of metal charged per day per furnace; pounds of composition ingot; pounds of new metal; pounds of gates and sprues; pounds of borings; pounds of other scrap.

15. Total pounds of metal poured per day per furnace, deducting all losses by oxidation or volatilization, or in the slag or skimmings.

16. Total pounds of metal recovered from slag, skimmings, etc., per furnace per day.

17. Gross percentage of loss during melting.

18. Net percentage of loss during melting, taking account of metal recovered from all metal-bearing refuse.

19. Average analysis of alloy produced.

20. Answer questions 8 to 19 for yellow brass, manganese bronze, or any other brass or bronze you have figures for.

21. Are your figures based on a single day's run, or are they averages? If the latter, on how long a period is the average based?

22. Discuss the relative advantages and disadvantages of the various types of furnaces you have tried. Is there any difference in the quality of the metal melted in various furnaces as regards physical tests, pressure tests, or as to its behavior in the foundry?

23. What precautions are taken to insure immunity of employees from accident, poisoning, or occupational disease?

24. To what extent are employees subject to "brass shakes," lead poisoning, etc.?

25. What precautions are taken to lay or remove poisonous fumes or irritating dust to which employees may be exposed?

26. Do you post notices and give instructions to employees in regard to hazards to which they may be subject? If so please send copies of notices and of instructions.

27. Please give any information along these lines you can that has not already been brought out by the questions.

28. In what way is the waste heat from your melting furnaces utilized? Have you any concentrating system at work on ashes, sweepings, skimmings, etc., for the recovery of waste?

Replies, so far as they apply to individual plants, will be held confidential by the Bureau of Mines.

A letter accompanying the questions contained the following statement:

The replies will be summarized for publication, but the communications themselves and the source thereof will be held strictly confidential.

About 350 such inquiries were returned unanswered, the firms being out of business, or having abandoned their work in brass and bronze. Of the 1,650 "live" firms to which inquiries were sent, about 280 replied, some 230 with data and some 50 with the statement that they kept no records that would enable them to give any data. Many of those replying gave figures for several types of furnaces, so that the aggregate replies are equivalent to about 300 fairly complete sets of data. The replies covered 28 States, the bulk of them coming, of course, from the States of New York, Pennsylvania, Illinois, Massachusetts, Ohio, Michigan, and Connecticut. States as widely separated as Maine, Georgia, and Washington supplied data.

The information obtained was supplemented by personal visits to some 80 foundries and rolling mills in 13 States. Admission was refused to only three plants, all rolling mills, one in New York City, one in Connecticut, and one in Massachusetts. At less than half a dozen plants, these also being mainly rolling mills, was information refused, the reason given being that the policy of the management did not permit the furnishing of information. The superintendents or chemists of most of these plants expressed themselves as desirous to cooperate, but unable to do so under the rules of the management.

In general the foundries showed a great interest in the work, as did most of the rolling mills.

It is believed that the data obtained represent the practice of the great bulk of the firms melting brass that keep records or make tests from which such data could be compiled. As the more progressive is the plant, the fuller the records that are kept, and the less the likelihood that easily preventable leaks are occurring, it is probable that the average practice of the firms not reporting is at least no better than the average of those that did report.

RELIABILITY OF DATA COLLECTED.

The information furnished varied in exactness and reliability. Some data represented estimates that were somewhat vague owing to lack of accurate records, the vagueness being greatest in the most important points, the loss of metal in melting, and the fuel consumption. In many of these reports there may have been a desire to put the best foot foremost, so again, it is improbable that the average in the plants reporting is any better than the figures given. All replies received that were complete enough to be of any value what-

ever have been included, as even estimates not based on actual accurate records, are, after all, estimates made by those in best position to know the facts. In some instances the records were shown and the accounting system was explained; in others, the replies themselves showed that the records were accurately kept. Many of the replies were either inconsistent in themselves, or so far at variance with ordinary practice as to call for comment. Further correspondence was had with the firms furnishing such replies, and many errors were subsequently corrected. A few of the replies (mentioned in the notes following the large table) were given on the question sheets and mailed without the firm name being furnished. If only a few letters had been sent to the town or city shown by the postmark, further correspondence sometimes showed the source of the replies, but if the replies were from large cities, identification was impossible.

On the whole, it is believed that the figures tabulated herein are in the main correct and, as regards most types of furnaces, sufficiently numerous to reflect the practice of the firms supplying them, the practice, as before stated, being probably better than the average of the total number of brass melters in the United States.

DETAILS PARTICULARLY STUDIED.

An attempt has been made to study in particular the following important details: Gross loss in melting; net loss in melting; methods of recovery of metal waste; fuel consumption per hundredweight of metal melted; methods of utilizing waste heat from furnaces; most efficient construction of a given type of furnace; most efficient operation of a given type of furnace; speed of melting (production per furnace per hour); furnace repairs; labor factor (metal melted per furnace tender per hour); effect of various types of furnaces and methods of operation on health and safety of the workmen; details requiring particular attention and further study as a step toward reducing waste.

GENERAL TYPES OF FURNACES IN USE.

NO ONE "BEST" BRASS FURNACE.

One point must be made at the outset. Although the investigation herein outlined dealt particularly with furnaces, the real problem, when all factors are considered, is the most economical heating of metal. Modern methods show that by eliminating the causes of hindrances and delays, as well as waste motions, and by establishing some suitable efficiency reward for the workmen, foundry production at many plants can readily be made twice as large as that obtained by former methods. Hence the furnaces are called upon to supply far greater quantities of metal a day than has been necessary in the past. If the furnaces can not be pushed so as to yield an increased supply, more furnaces must be put in, else the melting

capacity will not be properly balanced in regard to the molding space. Hence the problem of rapid melting of metal is equally as important as those of losses in melting and fuel efficiency. All factors must be taken into consideration.

Each foundry or casting shop is a problem in itself. Hardly two plants in the country deal with exactly the same alloys or have exactly the same line of work. The proper furnaces for a plant making chiefly huge manganese-bronze propellers may not be by any means the proper furnaces for one making very light castings from red brass. Fuel and labor conditions vary widely with the location of the shop.

Consequently there can be no such thing as one best brass furnace, nor even one best type. There probably is, however, for any given location and given set of conditions some best furnace or type of furnace.

The furnaces can be most readily studied by dividing them into types and then considering their applicability to different alloys and different shop conditions.

The main types of furnaces in actual commercial use may be grouped in several ways as to fuel used—into those using solid fuel, as charcoal, coal, or coke; liquid fuel, as fuel oil; or gaseous fuel, as natural, city, or producer gas. According to the method of construction of the furnace, they might be classified into tapping, tilting, and pit furnaces, or into those using crucibles or not using them. In a more detailed classification, the following types might be listed:

General types of furnaces in use.

No.	General designation of type of furnace.	Kind of draft.	Fuel burned.
1	Pit	Natural	Coke.
2	do	do	Anthracite coal.
3	do	do	Both coke and coal.
4	do	do	Both coal and charcoal.
5	do	Forced	Coke.
6	do	do	Coal.
7	do	do	Both coke and coal.
8	Tilting	do	Coke.
9	do	do	Coal and coke.
10	Pit	Natural	Oil.
11	do	Burner	Do.
12	do	do	Natural gas.
13	do	do	City gas.
14	do	do	Producer gas.
15	Tilting	do	Oil.
16	do	do	Natural gas.
17	do	do	Producer gas.
18	Pit	Natural	Bituminous coal.
19	do	Burner	Oil.
20	do	Natural	Do.
21	Open-flame tilting	Burner	Do.
22	do	do	Natural gas.
23	Reverberatory	do	Oil.
24	do	Natural	Bituminous coal.
25	do	Forced	Do.
26	Cupola	do	Coke.
27	do	do	Charcoal.
28	Reverberatory	Burner	Producer gas.
29	do	Natural	Oil.
30	Open-flame tilting	Burner	City gas.

NOTES.

Types 1 to 20 use crucibles; types 21 to 30 do not.

Types 1 to 27 have been used commercially in melting brass.

Types 18 and 19 take several crucibles per furnace.

Type 28 has probably been tried experimentally.

Type 29 is in use for melting nickel and copper scrap and may have been used for brass or bronze.

Type 30 is in use for melting copper.

Many other combinations of furnace and fuel are possible, but it is not known that they have been actually used in the United States. Other types suggested are the "semiproducer" furnace, burning bituminous coal, and furnaces burning powdered coal, either of which might be made in the crucible or reverberatory types. The former possibly and the latter certainly could also be made in the open-flame tilting type. The "surface or flameless-combustion" furnace, burning natural, city, producer, or other gas, is another suggested form which could be made in the crucible type and possibly in a type analogous to a reverberatory, either tapping or tilting.

ELECTRIC FURNACES USED IN EXPERIMENTAL MELTS OF BRASS, BRONZE, OR COPPER.

Experimental melts of brass, bronze, or copper have been made in the following types of electric furnace, with a view to commercial use:

Experimental electric furnaces used in melting brass, bronze, or copper.

1. Pit furnace, resistance type, carbon resistor in adjustable blocks, crucibles used. (Hoskins type.)
2. Tilting furnace, resistance type, granular carbon resistor, crucibles used.
3. Pit or tilting furnace, resistance type, solid, molded resistor, crucibles used. (Helberger and Conley types.)
4. Tilting (or tapping) reverberatory-type furnace, solid resistor in blocks, adjustable or nonadjustable, no crucibles. (Hoskins and Fitzgerald-Thomson types.)
5. Tilting furnace, indirect arc, no crucibles. (Stassano type.)
6. Tilting furnace, arc to slag, or slag resistance, or both, no crucibles. (Héroult, Snyder, and Wile types.)
7. Tilting (or tapping) furnace, pinch effect, resistance in molten metal, no crucibles. (Hering type.)
8. Tilting (or tapping) furnace, induction, resistance in molten metal, no crucibles.

An electric crucible furnace using a granular chromium resistor has been tried or suggested for experimental work. A tilting-crucible furnace with a metallic resistor has been partly or wholly designed with a view to commercial use. At present in the United States there seem to be no electric furnaces in regular commercial use for melting brass, bronze, or copper, though one is in use for an alloy of nickel and chromium. Electric furnaces for melting steel are, of course, in extensive commercial use.[a]

[a] Hamor W. A., Progress of the electric steel industry: Jour. Ind. Eng. Chem., vol. 5, 1913, p. 866.

GENERAL REMARKS AS TO CLASSIFICATION OF FURNACES.

Other subdivisions of the types classified above might well be made as to shape, as both round and square furnaces of the following types are in use: Natural-draft pit coal, natural-draft pit coke, forced-draft pit coke, forced draft tilting coke, and pit oil. There are also used commercially at least four shapes of tilting open-flame oil or natural-gas furnaces.

The pit and tilting furnaces using crucibles with oil burners could be greatly subdivided according to the shape of the combustion chamber, and these as well as reverberatory furnaces with oil burners should be divided according as to whether the oil is vaporized mainly by its own pressure, by high air pressure, or by steam pressure. Other divisions might be made according to the make of the furnace, particularly in the tilting, forced-draft, coke furnaces, pit and tilting, oil or gas, and open-flame oil or gas furnaces, but the furnaces are here considered according to types rather than according to make.

More or less information has been procured on all the 27 commercially used types, and information complete enough for tabulation has been obtained on all but Nos. 9, 17, 18, 20, 26, and 27 of the above list.

Nos. 3, 4, and 7, which burn mixed fuel, have been included under the predominant fuel, note being made that mixed fuel was used. After having taken into account the shape of a given furnace, whether the oil is vaporized mainly by its own pressure or by high-pressure air (steam being included under high-pressure air, and an air pressure of 2 pounds per square inch at the burner being taken as the dividing line), and whether the alloy melted is high or low in zinc content (10 per cent of zinc being arbitrarily taken as the dividing line), it has been found advisable to divide the data received into a tabulation with 39 subdivisions for ease in comparison.

GENERAL DESCRIPTIONS OF FURNACE TYPES.

PIT FURNACES.

Under pit furnaces, as a convenient name, are herein included all furnaces using a single crucible from which the crucible is lifted and carried bodily to the mold for pouring, whether the furnace itself is beneath the floor level and in an actual pit, whether partly above and partly below the floor level, or wholly above the floor level. The last form is sometimes called the "crucible lift-out." If the furnace is below the floor level and square, it is made of brickwork, reinforced by iron girders; if round, it is made of circle brick, usually set in an iron or steel casing, the whole being placed in the pit. In the lift-out form the iron or steel casing is practically always used.

NATURAL-DRAFT, PIT, COKE OR COAL FURNACES.

A characteristic construction of pit furnaces burning hard coal or coke under natural draft is a pit about 6 to 8 feet deep, of about the same width, and as long as the battery of furnaces. The width is divided about equally into runway and furnace setting. The runway for removing ashes is covered with an iron grating or iron plates. Transverse iron girders 3 or 4 feet from the bottom of the pit support the furnaces and setting. The furnaces are side by side, built of fire brick, each furnace usually having walls about 4 inches thick. The furnace bottoms consist of iron grate bars, usually hinged so as to drop any fuel and ash left on top of them into the pit below, and controlled by chains from the melting floor above. From a few inches to a foot from the top, at the back of the furnace, is a rectangular or square flue, which leads into a larger flue running back of the battery, this larger flue in turn leading to the stack. Fuel is placed on the grate bars, the crucible is set on the fuel, and more fuel is piled around the sides of the crucible, so that the coal or coke comes in direct contact with the crucible. A variously shaped cover, often of cast iron in dome shape or flat, of fire brick in an iron frame, of a solid fire-brick slab, or of cast steel or manganese steel, is provided, which may be swung aside, lifted off, or rolled back.

At some plants dampers are placed in the flues to cut out any furnaces not in action, or the flues in inactive furnaces may be plugged.

Pit furnaces for brass and bronze vary in capacity from 25 to 1,000 pounds. The average capacity is probably about 180 to 240 pounds.

Brannt[a] and Japing and Krause[b] discuss an old kilnlike form of coke-fired furnace containing several crucibles set in the fuel bed, the central or "king" crucible being surrounded by smaller ones, and the whole being covered with a dome-shaped roof leading to a stack. This was used for melting and mixing copper and zinc, but was plainly an outgrowth of the old form of furnace previously used in making calamine brass, in which calcined calamine ore (zinc oxide) and coal dust were mixed and charged into crucibles between successive layers of shot copper, and the crucibles slowly heated, when the zinc, reduced from the ore, distilled up through and alloyed with the copper, the charge melting to brass. This form of furnace evidently did not long survive the calamine process which is now merely of historical interest.

FORCED-DRAFT, COKE OR COAL, PIT FURNACES.

The arrangement for stationary pit furnaces burning coal or coke under forced draft does not differ greatly from the ordinary natural-draft form, save that instead of the ash pit being open to the air below the grate bars, it is inclosed so that air under pressure may be led into it.

[a] Brannt, W. T., Metallic alloys, 1896, p. 162.

[b] Japing, E., and Krause, H., Kupfer und Messing, 1912, p. 64.

OIL OR GAS PIT FURNACES WITH BURNERS.

Pit furnaces for use with ordinary oil burners, or with burners for natural, city, or producer gas, closely resemble the coal or coke pit furnaces. They are almost invariably built with an upright, cylindrical chamber (or very rarely with one of square cross section) for the crucible, from circle bricks or ring blocks held in a drumlike iron or steel shell. They may be sunk in a pit, flues to a stack being provided as in coke-pit furnaces. Many, however, are partly or wholly above the floor level and the products of combustion are carried off either by piping or by mere hoods hung overhead and attached to short steel stacks. Few of the covers are solid, as are normally those of coke, pit furnaces, but most of them have a hole in the center through which metal may be charged into the crucible. The crucible is set on a refractory crucible block and is thus raised a few inches from the bottom of the furnace. The burner is introduced through a hole near the bottom of the furnace, sometimes pointing directly toward the crucible, but as often tangentially, so as to produce a whirling flame that will encircle the crucible several times before emerging. In one make a spiral baffle is put between the furnace wall proper and the crucible, and the burner is at the bottom in order to give the whirling motion; in another, the burner is at the top and directed downward into a combustion chamber that is beside the furnace proper and is an enlargement of it, making a chamber somewhat oval in plan, with the crucible placed eccentrically. In other types a chamber is used that is pear-shaped in plan, with the burner entering from the side. In others, the burner is introduced into a cylindrical combustion chamber, placed horizontally to the vertical and larger cylindrical furnace chamber proper and attached to it near the bottom. In all of these designs the intent is to allow adequate combustion space and to bring the hotter part of the flame about the crucible instead of merely at its top or actually outside of the furnace.

The forms of oil burners used with these furnaces are legion. The United States Naval Liquid Fuel Board reported in 1904 that thousands had been patented then, and inventors of burners have not been idle since 1904.[a] The burners in foundry use may, however, be divided into two general classes—those using air at comparatively high pressures, an arrangement that both gives air for the combustion of the oil and atomizes the oil, and those using low-pressure air for combustion and atomizing the oil by pumping it at comparatively high pressure through a sufficiently small orifice in the burner. In some furnaces the air is preheated before delivery to the burner by bringing the inlet pipe through the flue through which the products of combustion pass; or the air may be passed around the furnace casing itself, in

[a] Report of the United States Naval Liquid Fuel Board, 1904, p. 340.

a hollow shell, or through a series of return bends in the inlet pipe, which is brought through the path of the hot products of combustion. The oil is seldom heated, except back of the pump in winter, and then only enough to make it fluid enough for the pump to handle, although in a few furnaces the oil is slightly preheated just before it enters the burner.

Pit furnaces using natural gas differ in no vital essential from those using oil, save in the burner used. Those using city gas are sometimes, and those using producer gas must almost of necessity be, equipped with a gas preheater or regenerative system in order to get the heats out quickly enough. The usual burner for city gas consists of a tubular ring with three or four tangential openings. The gas and the air (from a blower) are mixed just before entering the ring. This form of burner tends to give a whirling flame about the crucible. The burners at some plants are set at the top of the furnace and the waste gases taken out by a flue at the bottom, thus giving a down draft, but are more commonly placed at the bottom of the furnace.

Pit-type furnaces in general are built in a variety of sizes, from those taking a No. 18 crucible holding 50 pounds of brass, to a No. 600 holding 1,800 pounds, the most common size probably being Nos. 60 to 70 with a capacity of 175 to 200 pounds of metal. In the smaller sizes the crucibles of molten metal are lifted by suitable tongs and carried to the molds by hand, one to three men being required, according to the size of the crucibles; in the larger sizes the crucibles are lifted by a traveling crane.

Many pit furnaces are built by the user, whereas tilting furnaces are usually bought from a furnace maker. A few home-made oil or gas burners are found, but most burners are bought from dealers or furnace makers.

A type of pit furnace using a number of crucibles set in one pit and heated by fuel oil burning under natural draft is much used in crucible-steel practice. Instead of an atomizing burner being used the oil is run into a series of pans (usually two or three), one above the other, and drips from the upper ones into those below, burning from the surface of the pans and from the cascades of oil from pan to pan.[a]

This type is rarely used for brass and bronze. Data as to the experience of one plant using it on red brass are presented in the large table, and in the notes following, under reply 198 (p. 114).

A similar type of furnace, burning producer gas with regenerative heating, is used in crucible-steel practice,[b] and an illustration of one for brass or bronze is shown by Hiorns.[c]

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[a] For illustration and description of a typical furnace of this form, see editorial article in Foundry, vol. 40, Sept., 1912, p. 339.

[b] For drawing, see Stoughton, B, Metallurgy of iron and steel, 1908, p. 89.

[c] Hiorns, A. H., Mixed metals, 1890, p. 133.

TILTING FURNACES.

Tilting furnaces using a crucible to hold the metal are built to use oil, or gas, or coke, under forced draft. They resemble those of the pit type of oil furnaces that are not wholly or partly put in actual pits. The drum that forms the furnace proper is lined with fire brick and is placed on trunnions so that it may be tilted by a suitable mechanism. The crucible in nearly all of these rests on a refractory crucible block, is wedged into the furnace, and has a projecting lip or spout. When the metal is hot enough, the furnace is tilted and the metal poured into a carrying crucible or a transfer ladle and in this is carried to the mold. The melting crucible is usually narrower and deeper than those in lift-out (pit) furnaces.

Most tilting furnaces stand above the ground and, if large, an elevated charging platform is provided in order to make the charging of the metal less difficult for the furnace tender. Some, however, are partly below the floor level, and are tilted by hydraulically operated mechanism below the floor. Few tilting-crucible furnaces are built with a capacity smaller than 180 pounds and they may have a capacity as large as 1,500 pounds, but more commonly hold 300 to 700 pounds, 375 and 600 pounds being common sizes.

TILTING, FORCED-DRAFT, COKE FURNACES.

In tilting, forced-draft, coke furnaces of several makes, the body of the furnace is a cylindrical (square in a few) sheet-iron shell, lined with fire brick, and is provided with a closed panlike sheet-iron ash pit that makes a tight joint with the body of the furnace when in melting position. The body can be raised away from the ash pit and tilted to pour the metal. In some forms the ash pit is dropped or raised by pneumatic power instead of the body of the furnace being raised or lowered. At the bottom of the furnace body are the grate bars, on which rests a refractory crucible block which supports the crucible. The crucible, as in most tilting crucible furnaces, is taller than those for pit furnaces, with little or no bilge, and has a projecting lip for pouring. It is wedged into the furnace at the top.

Coke is used almost exclusively as fuel. In rare instances, as much as 50 per cent of coal is mixed with the coke. No furnaces of this type are known to be using coal alone.

The coke is placed on the grate bars and around the crucible, and forced draft is admitted in large volume but at low pressure (usually less than 2 ounces) into the ash pit below the grate. In some forms the air is preheated by being passed between the furnace shell and an outer casing.

With this type of furnace there is regularly used a feeder, or preheater, consisting either of an old crucible with a hole in the bottom,

or of a refractory funnel placed directly above the crucible. The metal is charged into the feeder and is preheated by the hot waste gases before being poked down into the crucible, or the furnace may even be run so that the metal melts in the feeder, runs down into the crucible, and is there brought to pouring temperature.

Most of these furnaces are provided with separate hoods leading to a stack to carry off the hot gases. Many of the hoods are made telescoping so as to come closely down to the top of the furnace when running, and may be raised to permit the furnace to be tilted.

Marteil[a] describes a French forced-draft tilting furnace in which the air blast, instead of entering beneath the fuel on the grate, is admitted through an outer casing around the furnace shell, and is forced down on the coke through a number of tubular passages in the refractory lining, the tubes being inclined at an angle of about 45° from the horizontal, so as to blow the air downward. This form does not seem to have been used in the United States.

TILTING, OIL FURNACES.

A tilting, oil furnace burning any oil, but especially designed for kerosene, was formerly on the market. The oil dripped by gravity flow into a cup set below the floor of the furnace. About the cup was a shield pierced with holes to admit air under natural draft. This furnace is no longer manufactured.

The common form of tilting, oil furnace uses an atomizing burner. This type is similar to the pit, oil furnaces for a single crucible, save that it is of larger capacity and on trunnions. There are a dozen or more widely used makes of this type, which, aside from minor variations in the mechanism for tilting or for lifting the cover, differ chiefly in the type of burner used, in its location in the furnace, and in the size and shape of the combustion chamber.

OPEN-FLAME, TILTING FURNACES.

Tilting furnaces without crucible, known as direct-flame or open-flame furnaces, consist of an iron or steel shell lined with fire brick, carborundum fire sand, or other refractories, and mounted on trunnions, so that by tilting the furnaces the metal may be poured into ladles. The oil or gas flame plays directly above the metal, and the heating comes partly from this and partly by radiation from the top of the furnace.

There are four largely used makes of these furnaces, one with an egg-shaped shell mounted horizontally on trunnions, with a hole at one end of the shell for the burner and another hole on the side through which the products of combustion pass and through which the metal

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[a] Marteil, V., Alliages et fonderie de bronze, 1910, p. 77.

is both charged and poured. This form of furnace may consist of two of these egg-shaped chambers, each with a burner at one end and with its own charging and pouring door, which may be closed by a hinged cover, but with the ends opposite the burners open. These chambers are mounted on trunnions, as usual, but with the open ends together and the chambers communicating. Charges of metal are placed in both furnaces, but only one burner is lit at a time. The cover on the charging door nearer the burner is closed and the one farther from it opened. Thus the products of combustion from the chamber nearer the active burner are made to pass into the chamber farther from it and out of the farther charging hole. Also the waste gases from the first chamber are made to preheat the metal in the second chamber. The metal in the first chamber is ready to be poured before that in the second is melted, or at least before it is up to pouring temperature. After the metal in the first chamber has been poured, that chamber is again charged with metal, but the second burner is lit instead of the first, so that the second chamber containing the preheated metal becomes the furnace proper and the first chamber is used as the preheater. The chambers thus alternate as melter and preheater throughout the day's run.

This arrangement must result in a saving of fuel, but the lining at the communicating ends of the chambers (middle of the assembled furnace) is subjected to very severe usage by the flame, so that the life of the lining at that point is short. Many of the double-chamber furnaces, though mounted together, are being used as two distinct furnaces, the doors at the charging openings of both chambers being left off for the escape of the products of combustion, and both burners being used.

Another type of open-flame furnace is in the shape of a long cylinder lying horizontally, the burner and the hole for charging and pouring being placed much as in the first type. A third type has a spherical lower part and a conical upper part, at the top of which is a charging door. Two, or even three, burners project through the conical part and direct their flames downward when the furnace is tilted into operating position. A projecting spout at the side allows the metal to be poured. This type of furnace is built to contain 100 to 30,000 pounds of metal. The larger sizes are used chiefly for making ingot from scrap.

A fourth type is practically a small oil-fired reverberatory, made tilting. The outside of the furnace is approximately rectangular, and the melting chamber has an oval hearth on which the molten metal lies in a pool a few inches deep and has an arched reverberatory roof. One form has a burner entering horizontally just above the pouring spout, with a charging door on top of the furnace; in another form the charging door is on the front end, just above the pouring

spout, and the burner is on the roof of the furnace, pointing down toward the metal.

In all the open-flame furnaces the metal is directly in contact with the furnace lining, no crucible being required.

The most common sizes of open-flame furnaces are charged with 500 to 750 pounds of metal at a heat, although those taking 1,000 to 2,500 pounds at a charge are by no means rare.

REVERBERATORY FURNACES.

Reverberatory furnaces are chiefly used for melting large quantities of metal, though their capacity ranges from one-half to 40 tons. In some of the larger sizes the metal is tapped into a long runner leading directly to the large mold to be filled, instead of the metal being carried in a ladle. In some the metal is dipped out instead of being tapped. Although this type is common in iron melting and in copper smelting and refining, the brass industry uses it more in reducing to ingots, borings, and other scrap than for strictly melting purposes. When scrap is being refined into reverberatory ingots, most of the zinc is intentionally driven out, the refiner aiming for a product high in copper, and buying the scrap merely as copper-bearing material.

In the navy yards, reverberatory furnaces are used both for refining and for melting metal for propellers and other heavy castings. Gates, defective castings, etc., too heavy to enter other types of furnaces without being cut up can be charged whole into reverberatory furnaces. When used for brass and bronze melting this type usually takes charges of 1 to 7 tons, and consists of a fire-brick shell, rectangular in plan, with a fire-brick or a baked-sand bottom, and with a roof arched from side to side and somewhat arched from front to back, in order to deflect the flame down on the metal. A camel-back roof is often used. They are fired with bituminous coal or with oil and though smaller are similar to the air furnaces used for melting iron [a] and the reverberatories used for smelting copper ores [b] and for refining copper. Illustrations of a camel-back form for soft coal are given by Dean,[c] Marteil,[d] Sexton,[e] and Hiorns.[f] When these furnaces are fired by soft coal, it is burned on a grate in the fire box at the front of the furnace, either natural or forced draft being used. When fired by oil the burners are usually at the side, and in both cases the products of combustion are led to the stack by

[a] For drawings see Stoughton, B., Metallurgy of iron and steel, 1911, pp. 343, 344.

[b] For drawings, see Mathewson, E. P., Development of the reverberatory furnace for smelting copper ores: Trans. 8th Int. Cong. App. Chem., vol. 3, 1912, p. 113.

[c] Dean, W. R., Hints on brass foundry: Metal Ind., vol. 11, 1913, p. 10.

[d] Marteil, V., Alliages et fonderie de bronze, 1910, p. 93.

[e] Sexton, A. H., Alloys, p. 274.

[f] Hiorns, A. H., Mixed metals, 1890, pp. 134, 135.

a flue at the back. They may be fired by oil burned under natural draft, pan system, this type being in use for melting nickel,[a] or the oil may be burned in atomizing burners, which may enter the furnace either at the front or the side, two or three burners being commonly used on the larger furnaces. Of course when oil is used the fire box is omitted.

Dimensions of reverberatories used for brass and bronze are given in the notes following the large table, under Replies 79, 80, 81, 82, 83, 173, 180, and 202, and data on their performance are presented in the table under the same reply numbers.

Reverberatory furnaces are not much used for charges of less than a ton, and hence have not found much use in foundries for ordinary melting purposes, most of the plants that could make use of a large quantity of molten metal at one time having adopted the open-flame oil furnaces, which are really a tilting type of reverberatory.

CUPOLA FURNACES.

The cupola furnace is little used for brass melting, except for large emergency repair work in shops having a cupola normally used for iron, but no other means of melting brass in large quantities, though many junk refiners have a small cupola that they use for running down very impure material, the ingot thus obtained being usually further refined in a reverberatory furnace. In the notes on the large table, under Reply 80, figures on a test of cupola melting in running down red-brass borings show a coke consumption of 17 pounds per hundredweight of metal and a metal loss of 8 to 10 per cent.

Buchanan[b] gives the fuel consumption on cupola melting as 13 pounds of coke per hundredweight and gives a metal loss of 7.93 per cent on bronze made from new metal and consisting of 90 per cent of copper and 10 per cent of tin, the tin being melted in the ladle and the copper melted in the cupola and tapped into the tin.

He gives a melting loss of 10.1 per cent on previously alloyed bronze of the same composition and states that the quality of the metal obtained was poor. He further states that melting in the cupola is the most expensive and uncertain of all melting methods practiced in the brass foundry.

Gresham[c] characterizes both cupola and reverberatory melting as wasteful.

Cupola melting is generally considered to give a poor quality of product.[d]

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[a] For description of furnace of this type see editorial article in Brass World, vol. 9, 1913, p. 41.

[b] Buchanan, J. F., Practical alloying, 1910, pp. 61, 62.

[c] Gresham, W., British manufacturing industries: Brass Founding, 1876, p. 133.

[d] Editorial, Casting a large copper ladle: Foundry, vol. 41, 1913, p. 543; Parry, W. H., What is brass?: Metal Ind., vol. 12, 1914, p. 28.

Aside from refining, the only known commercial use of cupola melting for brass and bronze in this country is among a few small foundries making sleigh bells as their chief product. In those plants, according to Sperry,[a] scrap yellow brass, and miscellaneous scrap, skimmings, etc, are charged into small furnaces consisting of a fire-brick wall with a flue opening into it and leading to a stack, against which is placed a sheet-iron casing, approximately in the shape of a half cylinder, lined with fire-brick or other refractory. A ladle lined with fire clay is put at the bottom of the furnace as a hearth to receive the metal. The ladle is removed at the end of the heat and the metal poured from it into the molds. The metal and the charcoal fuel, which is used instead of coal or coke because of the detrimental effect of sulphur-bearing fuels on metal melted in contact with them, are charged together into the furnace, and the blast from a small fan (in earlier days run by water power but now operated by electricity) is admitted through tuyères. The furnaces take about 60 pounds at a charge and turn out a heat an hour. The furnace both melts and refines yellow-brass scrap, a practically zinc-free metal resulting. Tin is added in the ladle after the heat is over if there was not enough in the original scrap.

No information is available as to fuel consumption or metal losses in the charcoal cupolas, but it is certain that practically all the zinc in the metal charged is lost. As, in cupola melting, the metal must run as drops or fine streams into the hearth, passing through the path of all the products of combustion, there is every chance for volatilization of the zinc; hence the use of a cupola is practically confined to the melting of bronze. There is a great chance for metal to be retained by the ash in such a furnace.

Gowland [b] describes the cupola furnace commonly used in Japan, with charcoal as fuel, for melting statuary bronzes.

Horner [c] describes a forced-draft, tilting, coke furnace, said to be used in England, with a preheater or feeder above the melting crucible proper. Instead of using the feeder merely as a preheater, as is the usual practice, coke is charged into the feeder with the metal, and an air blast is led into the feeder through tuyères, thus making a little cupola on top of the regular melting crucible. This scheme is not used in the United States.

SEMIPRODUCER FURNACES.

The gas-generating or semiproducer furnace should be mentioned because of the present-day interest in cheap fuel on account of the recent considerable increase in the price of fuel oil, and the general

[a] Sperry, E. S., The bell industry of East Hampton: Brass World, vol. 9, 1913, p. 3.
[b] Gowland, W., The art of working metals in Japan: Jour. Inst. Met. (British), vol. 4, 1910, p. 34.
[c] Horner, J., Furnaces for melting brass: Engineering (London), vol. 90, 1910, p. 561.

tendency toward an increase in the prices of anthracite coal and coke, rather than because of any present commercial use for brass melting in this country.

This type, as applied to brass melting, is only in the development stage. The basic principle is that of combining a small gas producer with a melting furnace, making gas from soft coal, anthracite coal, or coke, and utilizing both the sensible heat of the gas and that produced by its combustion. Marteil[a] illustrates a French tilting furnace of this type using petroleum coke. The crucible is supported over a bed of fuel but not in contact with it, combustion space for gas being provided both below and around the sides of the crucible. Air is blown into the fuel bed, but not in quantity sufficient for complete combustion. Another air inlet above the fuel bed and below the crucible supplies more air to complete the combustion. The waste gases are then led out over the surface of the metal in the crucible, the final exit opening being in the center of the cover.

An American patent describes a pit furnace to take a single crucible that rests directly on the coal (the patent does not specify whether anthracite or bituminous coal is to be used). Air alone, or, preferably, a mixture of air and dry steam, is blown into the fuel bed through a casing about the furnace bottom and then through a half dozen downward-pointing tubular openings in the refractory lining. No separate ports to admit air for combustion of the gas produced are provided, all the air entering through the half dozen openings and passing through the fuel bed.

Another design aims to obtain the advantages of cheap bituminous coal as a fuel and of hot producer gas by generating hot gas, retarding its combustion until it is delivered to the final heating zone, and then supplying air for combustion. The nature of the flame is to be regulated by controlling the air supply. This form has so far been applied chiefly to annealing furnaces, but the makers expect to apply it also to brass melting, either in a reverberatory type of furnace, or to a number of crucibles in the same melting chamber. The design calls for a rocking grate below the melting chamber which will be suspended above it. Steam is to be forced through a deep bed (probably 18 inches deep) of soft coal on the grate, and the heat of the producer gas thus made will serve to warm the bottom of the melting chamber.

The hot gas is then to be led up the sides of the melting chamber, supplying some heat to the sides. It is then to be admitted to the melting chamber through ports, and for its combustion, air, in a regulated supply, is also to be admitted at various ports. The gas will thus be burned within the melting chamber if crucibles are used, or over the metal if the furnace is of the reverberatory type.

[a] Marteil, V., Alliages et fonderie de bronze, 1910, p. 91.

A rather similar type of brass furnace of French design, using hot gas from a producer that forms part of the furnace, is illustrated by Damour.[a]

Suspending the melting chamber over the fire box or producer chamber, although doubtless practicable for annealing furnaces, would offer some difficulties in a reverberatory of large capacity. With such an arrangement the melting chamber would rest on the ground, the fuel would be burned in a fire box or producer at the front or side of the melting chamber, and the gas would be led to the melting chamber as before. Discussions and illustrations of brass and bronze melting furnaces in general are given by Krom,[b] E. L. S. N.,[c] and Horner.[d]

FURNACE DATA FROM THE LITERATURE.

Some information as to fuel consumption and loss of metal in melting may be gleaned from foundry literature and from catalogues of furnace makers, or from their advertisements in the foundry periodicals. Much of the information in the literature is of little use, because few data are available as to the following details: The percentage composition of the alloy; whether new metal, ingot, heavy scrap, or borings are used; the size of the crucible; whether the figures are based on a whole day's run and include the first heat, before the furnace has been heated up, or on a single heat with a hot furnace; whether the metal was raised to a high temperature for light castings, or only to a low one for heavy ones, and other variables that play a large part in both fuel consumption and metal loss.

Furnace makers' statements are usually to be taken as representing ideal conditions and not as reflecting actual practice, save when actual tests by users are reported by the furnace maker. Some data obtained from books, periodicals, and catalogues follow.

NATURAL-DRAFT, PIT, COKE FURNACES.

The maker of a rival (forced-draft) type of furnace states that in the natural draft, pit, coke furnace with No. 70 crucible the fuel consumption per hundredweight of metal is 70 to 95 pounds, and the melting loss on red-brass ingots, 3 to 4 per cent; on red-brass turnings, 4 to 5 per cent; and on yellow brass 5 to 6 per cent. The speed is given as three to four heats a day.

Another maker of a rival furnace states that the melting loss in this type on yellow brass, consisting of 87 per cent of heavy scrap and 13

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[a] Damour, E., Industrial furnaces, 1906, p. 99 (trans. by Queneau).

[b] Krom, L. J., The development of melting furnaces: Metal Ind., vol. 7, 1909, pp. 287, 324, 358, 404, 436, vol. 8, 1910, p. 80.

[c] E. L. S. N., Development of English melting furnaces: Metal Ind., vol. 8, 1910, p. 244.

[d] Horner, J., Furnaces for melting brass: Engineering (London), vol. 90, 1910, pp. 559, 654, 660, 726; Utilization of waste heat from brass furnace: Foundry, vol. 41, 1913, p. 113.

per cent of chips, is 3.5 per cent; on 100 per cent chips, 8 per cent; on 100 per cent heavy scrap, 4.4 per cent; and on alloyed ingot, 2 per cent.

Booth[a] gives the melting loss (alloy not stated) as 3.5 per cent; fuel consumption, 62.5 pounds per hundredweight; crucible life (size not stated), 20 heats.

Corse[b] says, "I have obtained from different people figures as to the natural-draft coke furnaces varying from 25 to 75 pounds of coke per hundredweight. I rather think the average will run between 40 to 50 pounds. I have seen results as low as 28 and 30."

It is stated[c] that the fuel consumption in this type is 40 to 50 pounds per hundredweight, and even as low as 25 pounds, but that the latter figure is to be taken with a grain of salt. The speed of melting is given as 4 to 6 heats in 9 hours, with a No. 70 crucible.

Wood[d] gives a loss of 5.4 per cent on red-brass chips and a fuel consumption of 66 pounds per hundredweight on yellow-brass chips, with coke as fuel, a loss of 5 to 7.6 per cent, with a fuel consumption of 63 to 65 pounds per hundredweight, with a No. 200 crucible, and on yellow brass, consisting of 93 per cent of new metal and 7 per cent of chips, a loss of 2.4 per cent.

Marteil[e] gives the fuel consumption as 50 pounds per hundredweight (alloy and crucible size not given).

Quigley[f] gives a loss of 3.25 per cent on melting a composition consisting of 88 per cent of copper, 5 per cent of zinc, 4 per cent of tin, and 3 per cent of lead.

Primrose[g] gives, for 160-pound heats in the natural-draft, pit, coke furnaces, melting gun metal, a fuel consumption of 44 pounds per hundredweight.

Clamer and Hering[h] put the coke consumption in pit furnaces at 45 to 50 pounds per hundredweight.

FORCED-DRAFT, PIT, COKE FURNACES.

Marteil[i] gives the fuel consumption in forced-draft, pit, coke furnaces as 30 to 32.5 pounds per hundredweight. The maker of the forced-draft furnace who gave the figures mentioned above for the natural-draft furnace gives for the forced-draft furnace (forced draft of 1½ to 6 ounces crucible No. 70) loss figures of 1 to 1.5 per cent, a

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[a] Booth, W. H., Liquid fuel and its combustion, 1904, p. 276.

[b] Corse, W. M., in discussion in Trans. Am. Brass Founder's Assoc., vol. 5, 1911, p. 40.

[c] Editorial, Replies to correspondents under "Brass-Foundry Difficulties": Foundry, vol. 40, 1912, p. 418.

[d] Wood, R. A., Some results from melting brass chips: Metal Ind., vol. 10, 1912, p. 378.

[e] Marteil, V., Alliages et fonderie de bronze, 1910, p. 71.

[f] Quigley, W. S., The brass foundry: Metal Ind., vol. 5, p. 358.

[g] Primrose, H. S., A discussion of modern brass founding: Foundry, vol. 90, 1912, p. 366.

[h] Clamer, G. H., and Hering, C., The electric furnace for brass melting: Trans. Am. Inst. Metals, vol. 6, 1912, p. 104.

[i] Marteil, V., loc. cit.

fuel consumption of 38 pounds per hundredweight, and a speed of 6 to 8 heats per day.

Another maker's figures are 1 per cent loss on heavy scrap and 1.5 per cent on borings (No. 60 crucible), the speed of melting being figured as 45 minutes per heat of red brass and 35 minutes per heat of yellow brass.

NATURAL-DRAFT, PIT, ANTHRACITE FURNACES.

McPhee [a] on material consisting of 75 per cent of heavy alloy and 25 per cent borings (84 per cent copper, 8 per cent zinc, 5 per cent tin, and 3 per cent lead, crucible No. 100) gives a melting loss of 3.5 to 4 per cent, a fuel consumption of 50 pounds per hundredweight, a crucible life of 15 heats, and a melting speed of 2.5 to 3 hours per heat in natural-draft, pit, anthracite furnaces.

Dean [b] puts the fuel consumption in this type at 65 to 95 pounds per hundredweight on red brass.

Webster [c] puts the coal consumption on yellow brass at 33 pounds per hundredweight.

Wood [d] gives on 100 per cent yellow brass chips (No. 70 crucible) a coal consumption of 64 pounds per hundredweight and losses of 5 to 7.6 per cent. On yellow brass, mostly heavy alloyed material, with 6 per cent chips, he gives a loss of 2.4 per cent. For brass consisting of 80 per cent of copper and 20 per cent of zinc, Clamer and Hering [e] give the fuel consumption as 40 pounds per hundredweight.

Lathrop [f] states that when (yellow) brass is remelted (the brass furnaces of Connecticut are almost exclusively natural-draft, pit, anthracite furnaces) a loss in weight of 4 to 6 per cent results.

Reichhelm [g] reports a coal consumption of 60 pounds per hundredweight (alloy and size of furnace not given). He states that he believes the furnace mentioned in the report to be as economical as any of its kind.

Bassett [h] gives the loss in melting yellow brass as 6 per cent of the zinc used (equivalent to 2 per cent of the melt) and the total loss between new metal and finished product as 10 per cent of the zinc used (or 3.5 per cent of the melt).

Wood [i] gives 34 pounds per hundredweight as the average fuel figure on yellow brass in rolling-mill practice; and for different mills using the same make of crucible, but with varying stack draft, a fuel

[a] McPhee, H., The oil or crucible furnace: Metal Ind., vol. 10, 1912, p. 461.
[b] Dean, W. R., Coal versus by-product coke in the brass foundry: Metal Ind., vol. 8, 1910, p. 461.
[c] Webster, W. R., in discussion, Trans. Am. Brass Founders' Assn., vol. 5, 1911, p. 40.
[d] Wood, R. A., loc. cit.
[e] Clamer, G. H., and Hering, C., loc. cit.
[f] Lathrop, W. S., The Brass Industry of Connecticut: 1909, p. 11.
[g] Reichhelm, E. P., The heating power of fuels: Amer. Mach., vol. 18, 1895, p. 22.
[h] Bassett, W. H., Zinc losses: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 164.
[i] Wood, R. A., How much coal does it take to melt a pound of brass: Metal Ind., vol. 11, 1913, p. 88.

consumption per hundredweight, and a crucible life, of (*a*) 67 pounds, 25 heats; (*b*) 50 pounds, 33 heats; (*c*) 33 pounds, 48 heats. Good fuel economy and good crucible life go together, as do poor results on each.

Buchanan[a] gives a coke consumption of 75 to 83 pounds per hundredweight and a melting loss of 0.9 to 1.1 per cent on new bronze consisting of 90 per cent of copper and 10 per cent of tin.

Sexton[b] gives for this type of furnace a fuel figure of 36 pounds per hundredweight (alloy not given) and states that by the use of a perforated inverted truncated cone instead of the ordinary grate bars the fuel consumption was cut from 107 to 44 pounds per hundredweight on gun metal. On red brass he gives a melting loss of 2.3 per cent.

Horner[c] states that in the natural-draft pit furnace 67 pounds of coke per hundredweight is a fair average, but later in the same paper gives a figure of 50 pounds per hundredweight.

FORCED-DRAFT, TILTING, COKE FURNACES.

One maker of forced-draft, tilting, coke furnaces reports that in a test of pure copper the average coke consumption per hundredweight of metal melted was 27 pounds, some heats being melted with 22 pounds per hundredweight. He gives 17 pounds as the figure on brass and bronze, and states in a recent advertisement that the life of the crucibles is 15 to 30 per cent longer than in pit furnaces. A fuel figure previously given by this maker was 12 pounds per hundredweight, and he stated in conversation that it had been as low as 6 pounds per hundredweight on red brass.

Corse[d] says that the fuel consumption with this type of furnace runs as low as 15 pounds per hundredweight.

Horner[e] states that with forced draft, and by the utilization of the waste heat, the coke consumption can be reduced to 15 to 25 pounds per hundredweight. Other figures given are: 14 pounds of coke per hundredweight on a 400-pound charge and 23 pounds per hundredweight on a 150-pound charge.[f]

Horner[g] gives for gun metal (88 per cent copper, 10 per cent tin, 2 per cent zinc) in an English furnace of this type a fuel consumption of 17 to 10 pounds per hundredweight, and in a German furnace, also of this type, 25 pounds per hundredweight with a 110-pound charge and 15 pounds per hundredweight with a 660-pound charge.

[a] Buchanan, J. F., Practical alloying, 1910, p. 62.
[b] Sexton, H., Alloys, pp. 260, 268.
[c] Horner, J., Utilizing the waste heat from brass furnaces: Foundry, vol. 41, 1913, p. 113.
[d] Corse, W. M., loc. cit.
[e] Horner, J., loc. cit.
[f] E. L. S. N., Development of English melting furnaces: Metal Ind., vol. 8, 1910, p. 294.
[g] Horner, J., Foundry plant and machinery: Engineering (London), vol. 90, 1910, p. 658.

Karr[a] gives the fuel figure at 14.3 pounds per hundredweight.

The figure given by Hughes[b] of 20 pounds per hundredweight on gun metal is included in the large table as Reply 204.

Marteil[c] gives a coke consumption of 15 to 20 pounds in 660 to 220 pound charges in one furnace of this type; in another, 15 pounds per hundredweight (220-pound charge melted in 30 minutes); 12.5 pounds (440-pound charge melted in 50 minutes) and 15 pounds in the largest size (660-pound charge melted in 1 hour 15 minutes). The crucible life is given as 55 to 60 heats. In still another of this type he gives 15 pounds per hundredweight for bronze and 13 pounds for brass, and in yet another, 13.2 pounds for gun metal (88 per cent copper, 10 per cent tin, 2 per cent zinc).

The furnace maker mentioned second in the discussion of natural-draft, pit, coke furnaces puts the loss in his furnace (a forced-draft, tilting, coke type) at 2.8 per cent on yellow brass consisting of 87 per cent of heavy scrap and 13 per cent of borings; at 7 per cent on 100 per cent chips; at 2.75 per cent on 100 per cent heavy yellow scrap, and 1 per cent on yellow ingot. The crucible (capacity 600 pounds) is said to have a life of 35 heats, and one lining a life of 350 heats.

The maker of another furnace of this type states that when hard, 72-hour, Connellsville coke is used, the fuel consumption runs from 18 to 20 pounds per hundredweight, and that it is not recommended that hard coal be used in this furnace.

Japing and Krause[d] give 10 to 20 pounds per hundredweight as the figures on this type.

PIT, OIL FURNACES.

Booth[e] gives on a 40-pound charge in a pit, oil furnace a fuel consumption of 3 gallons of oil per hundredweight, a melting loss of 1.5 per cent (alloy not given), and a crucible life of 30 heats.

Reichhelm[f] compares the figure of 60 pounds of coal per hundredweight, which he reports for a coal furnace, with one of 1.9 gallons of naphtha per hundredweight. The naphtha was "converted into gas." There is nothing in his paper to show whether this statement refers to true gasification or to mere atomization, and the size of the furnace and the composition of the brass melted are not given.

Clamer and Hering[g] give the oil consumption per hundredweight on bronze as 3.0 to 3.8 gallons and on brass as 1.8 gallons (type of oil

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a Karr, C. P. (In discussion): Trans. Am. Brass Founders' Assoc., vol. 4, 1910, p. 142.

b Hughes, G., Nonferrous metals in railway work: Metal Ind., vol. 9, 1911, p. 426; Castings, vol. 9, 1911, p. 13; Jour. Inst. Met. (British), vol. 6, 1911, p. 96.

c Marteil, V., loc. cit.

d Japing, E., and Krause, H., Kupfer und Messing, 1912, p. 92.

e Booth, W. H., Liquid fuel and its combustion, 1904, p. 276.

f Reichhelm, E. P., loc. cit.

g Clamer, G. H., and Hering, C., The electric furnace for brass melting: Trans. Am. Inst. Metals (vol. 6), 1912, p. 104.

furnace not given). One maker, for a furnace provided with a burner using low-pressure air and high-pressure oil, claimed an oil consumption of 2.96 gallons of oil per hundredweight on alloys running 86 to 75 per cent copper, and claimed a melt of 220 pounds in a No. 80 crucible in an hour with a melting loss of 1 per cent and a crucible life of 42 heats. A later claim by the same maker was that the time of the heat could be reduced to 90 per cent of the above figure, and the oil consumption reduced to 1.82 gallons per hundredweight.

The claim for another furnace of this type is 2 to 2.5 gallons of oil per hundredweight, with 1.5 per cent melting loss on red brass. Another claim is 3 to 1.75 gallons, and still another puts the oil figures at 5 to 2 gallons per hundredweight.

Yet another maker claims 2 gallons of oil per hundredweight and 1 per cent loss on red brass, and quotes a test by a user of his furnace that showed an oil consumption of 1.7 gallons per hundredweight and a loss of 0.5 to 0.6 per cent on bronze. Another claim (for an English furnace) on gun metal is a fuel consumption of 2 gallons per hundredweight on a 50-pound charge and of 1 gallon per hundredweight on a 500-pound charge.

Another maker gives figures of 2 gallons per hundredweight and 10 heats per day for a No. 70 crucible and a melting loss "less than in a coke furnace." Still another claims for a No. 70 crucible a fuel figure of 1.75 gallons per hundredweight. A test quoted by a maker of this type of furnace on red brass, mixed heavy scrap and borings, showed a fuel consumption of 2 gallons of oil per hundredweight (air preheated) and a melting loss of 1.4 per cent, with 180-pound charges (No. 60 crucible) and one heat per hour.

The maker of an oil furnace using a low-pressure air burner gives the following comparison of his furnace with one using high-pressure air, both using a No. 60 crucible and 165-pound charges: Low-pressure air—7 heats in 6.2 hours, oil consumption 1.6 gallons per hundredweight; high-pressure air—6 heats in 7.3 hours, oil consumption 3.3 gallons per hundredweight.

As makers of crucible oil furnaces usually build both pit and tilting types, the maker's claims above given may be taken to apply to either type. A few figures known to cover tilting furnaces are given below. The firm that made the natural-draft, tilting, oil (or kerosene) furnace when it was on the market stated that one size, of 165-pound capacity, would melt that quantity of copper in two hours from a cold start, successive charges being melted in less than an hour, the fuel consumption being 1½ gallons of kerosene per hour. The crucible was stated to last 50 heats. It was stated that "there is no smoke after the combustion chamber has been heated for a few minutes."

Sexton[a] gives, for oil consumption in the atomizing-burner type of tilting oil furnace, figures varying from 2.4 to 4.5 gallons and a loss figure (alloy not given) of 1.3 per cent.

Horner,[b] on gun metal, states that 400 to 600 pounds may be melted per hour in this type, with 1.5 per cent loss.

The following figures are quoted by one maker from a recent test: No. 275 crucible; 3,244 pounds of material, consisting of 90 per cent of copper, 3 per cent of zinc, and 7 per cent of tin, melted in 6¾ hours; first four heats each of 711 pounds; fifth heat of 400 pounds; first heat took 1 hour 41 minutes and used 2.8 gallons per hundredweight; second heat took 1 hour 18 minutes and used 1.8 gallons per hundredweight; third heat took 1 hour 10 minutes and used 1.6 gallons per hundredweight; fourth heat took 1 hour 12 minutes and used 1.6 gallons per hundredweight; fifth heat took 48 minutes and used 2 gallons per hundredweight; average fuel consumption, 1.95 gallons per hundredweight.

Another furnace maker claims a fuel consumption of 1.75 gallons per hundredweight on 400-pound heats.

McKinnon,[c] on red brass and gun metal containing 12 per cent of borings and melted in a tilting crucible oil furnace, gives a fuel consumption of 3.75 gallons per hundredweight and a gross loss of 4.6 per cent, which included such foundry losses as those in grinding, as well as the actual melting loss.

Lenning[d] gives figures on the melting of 5,300 pounds of various bronzes in 9 hours 20 minutes in a German tilting, oil-fired, crucible furnace, using an air pressure of about 7 pounds per square inch and taking 660 pounds of metal at a charge. The figures show an oil consumption of about 2 gallons per hundredweight and melting losses ranging from 0.2 to 1.13 per cent and averaging about 0.7 per cent.

TILTING, OPEN-FLAME, OIL FURNACES.

Makers claim that for different sizes of tilting, open-flame, oil furnaces with capacities of 450 up to 2,700 pounds the oil consumption is 2 to 1.5 gallons per hundredweight, and for another style, with capacities of 330 to 1,770 pounds, that the oil consumption is 1.75 to 1.25 gallons.

For different furnaces with capacities of 100 to 30,000 pounds another maker gives an oil consumption of 2.25 to 1.25 gallons per hundredweight and quotes a user as getting 0.5 per cent melting loss in this type of furnace on material consisting of 84 per cent of copper, 3.5 per cent of zinc, 12.5 per cent of tin, and 0.5 per cent of lead.

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[a] Sexton, A. H., Alloys, p. 268.

[b] Horner, J., Foundry plant and machinery: Engineering, vol. 90, 1910, p. 658.

[c] McKinnon, H. P. (in discussion): Trans. Am. Brass Founders' Assoc., vol. 5, 1911, p. 41; Met. Chem. Eng., vol. 9, 1911, p. 364.

[d] Lenning, P., Oelfeurung, System "Buess": Giesserei Zeit., vol. 10, 1913, p. 305.

A third make is stated to use 2 gallons of oil per hundredweight, and other figures are $1\frac{1}{3}$ to 2 gallons.

Smith [a] gives 3 gallons of oil per hundredweight as a normal figure on material running one-sixth borings (red brass).

McPhee [b] gives figures showing a melt of 700 pounds of material consisting of 80 per cent of copper, 10 per cent of tin, and 10 per cent of lead, in 45 minutes, with an oil consumption of 2.15 gallons per hundredweight.

Sexton [c] gives 2.25 to 1.35 gallons per hundredweight as the oil consumption in furnaces of this type.

Parry [d] reports the use of 2 gallons of oil per hundredweight of ordinary red brass consisting of 86 per cent copper, 5 per cent tin, 5 per cent zinc, and 4 per cent lead, of which a third or more is charged in the form of gates and sprues, some chips also being used. He gets 6 heats per day from each furnace of 1,000 pounds capacity, and obtains 3,666 heats before relining the furnace.

Booth,[e] on heavy alloyed red brass in 350 to 500 pound charges, gives a fuel consumption of 2.44 gallons per hundredweight and a melting loss of 2.25 per cent.

Quigley,[f] on an alloy consisting of 88 per cent of copper, 5 per cent of zinc, 4 per cent of tin, and 3 per cent of lead (which lost in pit coke furnaces 3.25 per cent) gives a loss of 3.18 per cent and a fuel consumption of 1.53 gallons per hundredweight in an open-flame furnace. He also gives a figure on bearing metal (40 per cent new metal, rest scrap) of 1.62 gallons per hundredweight.

On high-zinc alloys in the open-flame oil furnace one maker claims less than 10 per cent loss on manganese-bronze borings.

Jones [g] gives gross melting losses on manganese-bronze ingots and gates as 4.3 per cent, as compared with 6.1 per cent on the same in a pit coke furnace.

Weeks [h] gives on yellow brass a net melting loss of 1.3 per cent and an oil consumption of 1.8 gallons per hundredweight.

Reardon,[i] on an alloy consisting of 73 per cent of copper, 18 per cent of zinc, 2 per cent of tin, and 7 per cent of lead, with 46 per cent of new metal, no borings, gives figures showing 7 heats of 650 pounds each in 6 hours, with a fuel consumption of 2.4 gallons per hundredweight and a loss of 1.13 per cent.

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[a] Smith, J. (in discussion): Trans. Am. Brass Founders' Assn., vol. 5, 1911, p. 41.

[b] McPhee, H., The oil or crucible furnace: Metal Ind., vol. 10, 1912, p. 465.

[c] Sexton, H., Alloys, p. 277.

[d] Parry, W. H., Brass-foundry furnaces: Metal Ind., vol. 11, 1913, p. 423.

[e] Booth, W. H., Liquid fuel and its combustion, 1909, p. 276.

[f] Quigley, W. S., loc. cit.

[g] Jones, J. L., The effect of repeated melting on manganese bronze: Trans. Am. Brass Founders' Assn., vol. 5, 1911, p. 128.

[h] Weeks, C. A., Melting nonferrous metals in an electric furnace: Met. Chem. Eng., vol. 9, 1911, p. 363.

[i] Reardon, W. J., The manufacture of high-copper castings: Metal Ind., vol. 8, 1910, p. 212.

Jones [a] gives the following average melting losses per hundredweight in open-flame furnaces: Copper, 1 per cent; red brass, 1½ per cent; yellow brass, 2 per cent; copper turnings, 1½ per cent; red-brass turnings, 2 per cent; yellow-brass turnings, 3 per cent; ingot aluminum, 0.5 per cent.

Hansen [b] gives figures for three types of open-flame furnaces. The alloy consisted of 81 per cent of copper, 16.5 per cent of zinc, 1.5 per cent of tin, and 1 per cent of lead, 50 per cent being new metal, 30 per cent heavy alloyed scrap, and 20 per cent borings. Under ordinary running conditions the figures were: Furnace A—1,000-pound charge, 88 minutes per heat, 3.5 gallons of oil per hundredweight, 5.8 per cent loss; furnace B—750-pound charge, 71 minutes per heat, 2 gallons per hundredweight, 2 per cent loss; furnace C—750-pound charge, 85 minutes per heat, 2 gallons per hundredweight, 3 per cent loss. Under careful test conditions furnace A, on 1,000-pound charges, averaged 43 minutes per heat, 2 gallons of oil per hundredweight, and 2.3 per cent loss; furnace B, on 700-pound charges, averaged 64 minutes per heat, 1.8 gallons of oil per hundredweight, and 1.8 per cent loss.

Furnace A, in electrical energy for the motor running the air blast for the burner, used 1.14 kilowatt-hours per hundredweight of metal melted, whereas this furnace under test conditions and all the tests on furnaces B and C averaged about 0.65 kilowatt-hour for the blast used in melting 1 hundredweight.

REVERBERATORY, COAL FURNACES.

Marteil,[c] for a 4-ton reverberatory, gives a coal consumption of 30 to 35 pounds per hundredweight and a melting loss of 6 to 8 per cent (alloy not given).

Buchanan [d] gives a coal consumption of 80 pounds per hundredweight and a melting loss of 3.6 per cent on an alloy consisting of 90 per cent of copper and 10 per cent of tin from new metals.

Sexton [e] gives a figure of 50 pounds of coal per hundredweight, and states that in a furnace taking 5 tons at a heat this is reduced to 33 pounds (alloy not given).

Hiorns [f] states that the reverberatory is used chiefly for melting yellow metal, but that the loss of zinc is so great that most (British) foundries have gone back to crucible melting.

Primrose,[g] describing English practice, states that for small gun-metal work the pit furnace is suitable where the output is not large,

[a] Jones, J. K., Shrinkage: Metal Ind., vol. 11, 1913, p. 267.

[b] Hansen, C. A., Electric melting of copper and brass: Trans. Am. Inst. Metals, vol. 6, 1912, p. 116.

[c] Marteil, V., Alliages et fonderie de bronze, 1910, p. 94.

[d] Buchanan, J. F., Practical alloying, 1910, p. 62.

[e] Sexton, A. H., Alloys, p. 274.

[f] Hiorns, A. H., Mixed metals, 1890, p. 127.

[g] Primrose, H. S., A discussion of modern brass founding: Foundry, vol. 90, 1912, p. 363 et seq.

but that for larger work a reverberatory, or air furnace, of suitable size is advantageous. He cites a test on a heat of 14,000 pounds of gun metal, consisting of 30 per cent of new metal, 15 per cent of borings, and 55 per cent of scrap, which was melted in 6½ hours, 26 pounds of splint coal per hundredweight being used, but states that 20 pounds per hundredweight is the usual fuel consumption. The calculated analysis was 87 per cent copper, 9.7 per cent tin, 2.7 per cent zinc, and 0.6 per cent lead. The actual analysis showed 87.9 per cent copper, 9.5 per cent tin, 2.0 per cent zinc, and 0.6 per cent lead, a composition that would mean a melting loss of about 1 per cent.

Japing and Krause [a] give a fuel consumption of 25 to 50 pounds per hundredweight and a melting loss of 6 to 12 per cent, seemingly for bronze.

GAS FURNACES.

The following figures for gas-fired furnaces are found in the literature. One maker of tilting-crucible furnaces, for a 275-pound charge, gives a consumption of natural gas of 225 cubic feet per hundredweight of metal. In the open-flame, natural-gas, tilting furnace, Reardon [b] gives the following figures for an alloy consisting of 73 per cent of copper, 18 per cent of zinc, 2 per cent of tin, and 7 per cent of lead, with 46 per cent of new metal and no borings; 7 heats of 650 pounds each were made in 10 hours, with a gas consumption of 144 cubic feet per hundredweight, and a melting loss of 2.7 per cent.

The makers claim for one type of open-flame natural-gas furnace a fuel consumption of 220 to 330 cubic feet per hundredweight, and for another a fuel consumption of 245 to 280 cubic feet per hundredweight. Another furnace maker gives 186 to 230 cubic feet of natural gas, or 278 to 416 cubic feet of city gas per hundredweight. Still another says, in a recent advertisement: "Our fuel-oil furnace has been equipped with a new burner for gas, which burns either natural or artificial gas. The results of the tests show that gas has coal or coke beaten, although it does not beat fuel oil in cost of operation."

The loss in refining borings in an 18,000-pound natural-gas reverberatory furnace is given as 1.4 to 2.8 per cent.[c]

No figures on fuel consumption in gas-fired reverberatory brass furnaces are available. Johnson [d] states that in the most improved open-hearth steel furnace, 500 cubic feet of natural gas yielding 1,045 British thermal units per cubic foot and under an 8-ounce pressure is used in melting a ton of steel, or 250 cubic feet per hundredweight. The gas consumption on brass should be considerably less.

[a] Japing, E., and Krause, H., Kupfer und messing, 1912, p. 86.

[b] Reardon, W. J., loc. cit.

[c] Anonymous, Foundry, vol. 91, 1913, p. 129.

[d] Johnson, N., Use of natural gas in the manufacture of open-hearth steel: 8th Int. Cong. App. Chem. 1912, vol. 25, p. 685.

Campbell[a] states that city gas has been substituted for coke in melting gold in the British mint, a crucible of double the capacity of the one formerly used in the coke furnaces being employed. The fuel cost was $4\frac{1}{4}$ pence per hundredweight with gas, as compared with 7 pence with coke (actual fuel consumption not given), and the metal losses have decreased. The crucibles last 18 heats, as compared with 12 heats for the smaller crucibles in the coke furnaces. The gas is burned in a burner taking air under a pressure of 2 pounds per square inch and gas under a pressure of about 2 ounces per square inch. Campbell states that at the mint oil furnaces that used burners taking air under a pressure of 2 to 2.5 pounds per square inch have been tried. The oil was more economical than coke, but the furnaces were too noisy.

One furnace maker claims a fuel consumption of 350 cubic feet of city gas per hundredweight of hard brass melted, the gas yielding 650 British thermal units per cubic foot.

DETAILED RESULTS OF INVESTIGATION.

EXPLANATION OF TABULATION OF REPLIES.

In order to facilitate comparison of the performances of different furnaces of the same type under approximately like conditions, the data obtained in reply to the list of questions relative to brass-melting practice have been compiled in one large table with 39 subdivisions. It should be remembered, however, that in no two plants are conditions exactly alike, so that no one set of figures can be considered as exactly comparable with any other. In comparing any two figures in one column for any two replies, all the data tabulated, as well as the notes on the reply numbers following the tables, should be taken into account. One great variable, of which no account can be taken because measurements of the temperature of the metal are rare, is the temperature to which the metal is heated before leaving the furnace. Another variable that exerts a vast influence is promptness of pouring—whether the metal is taken from the furnace just as soon as it is ready to be poured, or whether it is allowed to remain ("soak") in the furnace after it is ready. Still another variable is the volume of air and products of combustion passing through the furnace in a given time. The draft in a natural-draft furnace is seldom known, and varies from day to day. This variation of course affects fuel consumption and speed of melting, as well as loss of metal.

Information that could not be readily tabulated, but throwing light on the conditions under which the furnace is used, has been given in the notes following the table.

[a] Campbell, J. F., Forty-first Annual Report of the Deputy Master and Comptroller of the (British) Mint, 1911, p. 31; Forty-second Annual Report, 1912, p. 35.

In the table for each fuel a subdivision is made for each of the following points: Whether an alloy high or low in zinc is produced; whether a furnace is used under natural draft or forced draft; whether the furnace is pit, tilting, or reverberatory; whether the furnace is round or square; whether one crucible, several, or none is used; and whether an oil burner works under high or low oil or air pressure. Ten per cent of zinc has been arbitrarily taken as the dividing line between alloys of low and high zinc content, and an air pressure of 2 pounds per square inch at the burner has been taken as the dividing line between high and low air pressure oil burners.

The items of the investigation are given in the vertical columns and are numbered. A full explanation of each item is given in the following paragraphs:

Item 1. Reply No.—This item gives the consecutive number assigned to replies as received.

Item 2. Nature of plant.—According to their nature, plants have been divided into jobbing foundries (those making castings and perhaps doing machine work, but not putting out a finished product ready for final consumption—designated "Job" in table); manufacturing plants (those making castings that go into a finished product made by the same plants—designated "Mfg." in table); rolling mills ("Roll."), and refining plants ("Ref."). A refining plant melts borings and other scrap into ingots, and may be operated by a firm with that as its main business, or the plant may be a department of a manufacturing plant.

Item 3. Height or shape of furnace.—This item gives inside height in inches of the main chamber. In open-flame furnaces this item gives the furnace shape.

Item 4. Diameter or inside length of furnace.—This item gives the inside diameter of the furnace, if round, or the inside length of a side, if square.

Item 5. Fuel and air supply.—This item gives grade, size or specific gravity, analysis, and heat units of fuel, stack draft in inches of water or natural draft, pressure in pounds or ounces per square inch of air in the fire box or ash pit of forced-draft furnaces, and of air, oil, or gas at the burner for oil or gas burners.

Item 6. Analysis of charge.—This item shows the percentage of copper, zinc, tin, and lead to the closest half of a per cent. In many cases the figures reported in other columns are for all alloys melted, whereas the analysis given is for the alloy most used. When such cases are known, mention thereof is made in the notes. The following abbreviations are used: R. B. for red brass, approximately 85 per cent copper, 5 per cent zinc, 5 per cent tin, and 5 per cent lead; Y. B. for yellow brass, approximately 66 per cent copper and 34 per cent zinc, with

or without a little lead; Bz. for bronze, approximately 90 per cent copper and 10 per cent tin; Mn. Bz. for manganese bronze, approximately 56 per cent copper and 41 to 42 per cent zinc, with some iron, tin, aluminum, and manganese; G. S. for German silver, approximately 62 per cent copper, 23 per cent zinc, and 15 per cent nickel; Pb. Bz. for leaded bearing bronze of say 78 per cent copper, 7 per cent tin, and 15 per cent lead. The abbreviations are used only when no more definite information as to the composition of the alloy is stated.

Item 7. Composition of charge.—This item has been divided into new metal, heavy alloy, such as "composition ingot," gates, sprues, defective castings, and all heavy scrap; and light alloy, such as chips, borings, turnings, and small pieces of thin punchings from sheets.

Item 8. Crucible maker's No.—Standard sizes of crucibles usually hold nearly 3 pounds of molten brass per number; that is, a No. 60 crucible, when new and full, holds about 180 pounds. Crucibles from various makers vary somewhat in capacity and in form. The standard crucible for tilting furnaces is tall. Special crucibles (usually of taller form than the standard) are denoted by "sp."

Item 9. Weight of charge.—In open-flame or reverberatory furnaces Item 9 is rated capacity in pounds. This item is for a single heat. In double-chamber open-flame furnaces, used as such, both chambers are regarded as a single furnace. If used separately, each chamber is regarded as a furnace.

Item 10. Heats per day.—This item refers to an individual furnace.

Item 11. Hours per day.—This item refers to the furnace and not necessarily to the whole shop, as in natural-draft pit furnaces the fires are sometimes lighted early by the night watchman, and in other cases the furnaces may not run as long as the shop. The hours given, in general, are to be taken as not counting the noon hour or half hour. In natural-draft pit furnaces melting usually goes on during this time as fast as during regular working hours. In tilting furnaces, the furnaces are usually either empty over noon or else the oil or gas flame (or blast in tilting coke furnaces) is lowered.

Item 12. Hours per heat.—This item is calculated from items 10 and 11.

Item 13. Furnaces per tender.—This item is intended to count furnace helpers as tenders, and has seemingly been generally so reported. Possibly in some cases the helper's work has not been included. The basis for this item, and the one depending on it, item 17, metal per tender per hour, will vary in different plants, as in some plants the furnace tender sorts scrap, weighs metal, fires and charges the furnaces, pulls the pot, and may even help carry it to the mold, whereas in others the charges are weighed out from the

stock room and brought to the tender in tote boxes, and in others the pots are pulled and poured by a separate gang of men. In the case of rolling mills items 13 and 17 refer to each man of the gang, which usually consists of a caster, his helper, and a mold man. Hence the rolling-mill production per man per hour is figured on a different basis from that in other shops because of the impossibility of separating the duties of the individuals in the gang.

Item 14. Metal per furnace per day.—This item is figured from the weight of the charge and the number of heats.

Item 15. Metal per furnace per hour.—This item is figured from items 14 and 16.

Item 16. Time per hundredweight of metal melted.—This item is the reciprocal of item 15.

Item 17. Metal per tender per hour.—This item is explained under item 13.

Item 18. Life of crucibles.—This item refers to the number of heats obtained before the crucible is discarded. Obviously, no figures appear for open-flame or reverberatory furnaces.

Item 19. Life of lining.—This item refers to large repairs, when practically a whole new lining is put in, not to patching or minor repairs, unless so stated.

Item 20. Fuel consumption per hundredweight of metal melted.—The figures for this item should be read with constant reference to the figures representing the analysis and composition of the charge and to the notes following the table.

Item 21. Gross melting loss.—The questions were intended to bring out merely furnace losses, but the figures in practically all replies, save those marked "special" under item 25, are on total losses and represent the difference between metal charged into the furnace and that obtained as castings, gates, and sprues. Thus they include melting losses proper (oxidation and volatilization and loss in skimming and by spilling into ashes) and also metal lost by being spilled into shot in pouring, losses in grinding the castings, metal stolen, and any other foundry losses.

Item 22. Net melting loss.—This item represents the gross loss, less the recovery from skimmings, spillings, ashes, or any other recovery on the gross loss.

Item 23. See notes on page 70.—The notes following the table give the comments made by the communicating firms as to the value of different types of furnace they have used, or on special conditions that exist in their plant. If such a note is given for any reply number, it should be read in connection with the tabulated figures, in order to make more clear any special variables that may affect the results presented in the table.

Item 24. Conditions of test, average or special.—When "special" appears in this column, it means that the data, at least the fuel-consumption and metal-loss figures, are based on special tests, and not on running conditions. In other cases the data are based either on foundry records of average running conditions, or on estimates of such conditions, and are then designated "average."

GENERAL COMMENTS.

A blank under any item means that no data were supplied on that point. If certain conditions greatly affect any result tabulated, reference (denoted by †) is made to the notes following the table. A question mark following a result means that its accuracy is extremely doubtful and that the result could not be satisfactorily verified.

The notes following the table generally give the exact words of the reply received from a plant, though in some cases the reply has been paraphrased slightly for brevity. Other replies constitute information given in conversation on a visit to the plant. Any comments by the writer of this bulletin are in brackets. The notes do not necessarily represent the ideas of the writer.

Different replies on the same type of furnace usually show a wide variation of opinion, so that many of the replies are mutually contradictory. In order to show this variation, and the different sets of conditions existing in different plants that lead to such varying results, and to so many different points of view, as well as for the intrinsic information in them, the notes are given more fully than would have been justified had it not been important to bring out forcibly the fact that such differences of opinion and of conditions do exist.

Details of brass-melting practice in various types

[* designates estimated results rather than results based on average running conditions.]

1. ROUND, PIT, NATURAL-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5	6				7			8	9
		In.	*In.*		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		*Lbs.*
2	Mfg.	....	....	72-hour Connellsville coke; 12,650 B. t. u.; volatile matter, 0.32; carbon, 86.6; ash, 13.1; sulphur, 1.0.	R. B.	....	....	....	....	....	....	100	250
7	Job.	....	....	72-hour Connellsville coke.	83	7	4	6	Some.	Mostly.	None.	80	200
8	......	....	....	....	85	5	5	5	75	25	......	80	225
9	Mfg.	36	17	By-product; 13,600 B. t. u.; draft, 0.17 inch of water.	89	2	7	2	75	25	Some.	70	187
14	Ref.	42	27	Coarse, 72-hour Connellsville coke; volatile matter and moisture, 1.5; carbon, 85.5; ash, 12, sulphur, 1.0 to 1.7.	83	7	4	6	....	....	100	250	600
16	Mfg.	33	15½	70-hour Connellsville coke.	R. B.	....	...	....	....	....	None.	40	120
18	Job.	30	....	72-hour Connellsville egg.	R. B.	....	....	....	.....	....	Much.	90, 80	250, 200
34	Mfg.	34	17	Connellsville............	85	5	5	5	....	....	......	70	200
35	..do..	36	17	10.8 per cent ash; 0.56 per cent sulphur.	R. B.	....	....	....	....	....	......	50	150
51	..do..	....	14	Crushed; 13 per cent ash; 1 per cent sulphur.	†85	6	6	3	25	75	......	18	55
53	......	24	18	....	R. B.	....	....	....	....	....	......	(*a*)	*c* 200
64	Job.	30	18	Crushed Connellsville large stove.	88	8	3	4	10	20	70	60, 80	170
64	..do..	30	20	.....do..................	88	8	3	4	10	20	70	100	275
67	Mfg.	28	18	70-hour Connellsville....	80	10	....	10	50	Some.	Some.	40, 50	*c* 140
75	..do..	27	15½	Egg.....................	83	4	Bal.		50	....	......	50	150
76	..do..	30	18	48-hour Connellsville....	85	5	5	5	50	50	......	60	180
77	......	....	....	....	85	5	5	5	25	50	25	60	180
82	Mfg.	44	20	Connellsville; ash, 10 per cent.	80	4	8	8	70	30	......	70	200
82	..do..	48	26	.....do..................	80	4	8	8	70	30	......	125	310
97	..do..	....	....	48-hour..................	R. B.	....	....	....	30	55	15	60, 80	....
101	..do..	39	20	Connellsville............	80	10	5	5	....	....	......	(*a*)	....
113	Job..	30	20	48-hour Connellsville....	84	8	2	6	35	25	40	70	190
114	Mfg.	....	....	....	R. B.	....	....	....	....	....	......	50	125
119	..do..	25	18	72-hour Connellsville egg.	R. B.	....	....	....	....	....	......	40, 60, 80	....
125	Job..	25	18	.....do..................	R. B.	....	....	....	....	....	......	30, 40	110
126	Mfg.	30	19	By-product...............	85	6	4	5	35	Some.	Some.	60, 70	152
129	......	....	22	72-hour..................	91	2	7	....	50	45	5	60, 80	135
133	Job..	32	17	Connellsville............	R. B.	....	....	....	50	30	20	45	130
142	Mfg.	33	24	....	83	10	3½	3½	....	....	......	70	200
148	Job..	30	16	....	R. B.	....	....	....	75	25	Some.	20	50
153	Mfg.	36	19	....	88	2	9	1	61	26	13	70	180
161	Job..	36	19	72-hour..................	80	8	7	5	15	85	......	70	200
162	Mfg.	34	17	.....do..................	86	3	11	....	40	40	20	25–35	*c* 51
163	..do..	33	20	.....do..................	80	....	10	10	....	....	......	*b* 100	340
168	......	32	20	....	R. B.	....	....	....	....	....	None.	25, 30	50
177	Mfg.	36	18	72-hour..................	77	5½	6½	11	55	20	25	45	135
182	..do..	60	24	By-product; 12,765 B. t. u.; moisture and volatile matter, 14; ash, 14.4; carbon, 71.6.	R. B.	....	....	....	33	....	67	100–175	*c* 500

a See also figures for a special test described in the notes following this table, under the reply number for these figures.

b Patched every 70 heats.

c Less than 4 2. See notes on reply 9.

of furnaces and with various fuels.

† indicates that the notes on the reply number affect significance of figures so designated.

FURNACES MELTING LOW-ZINC ALLOYS.

Speed of melting.											Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Lbs. coke.*	*Pct.*	*Pct.*		
4	10	2.5	3	1,000	100	1.4	300	†18	......	50	......	3.4	70	Average.[a]
5	9	1.8	5	1,000	111	0.9	555	30	1,200	25–30	......	3.0	73	Do.
3	10	3.3	5	775	78	1.3	388	30	1,200	......	......	2.3	73	Special.
4	11	2.7	4	748	68	1.3	544	27	(*b*)	37	(*c*)	....	74	Average.
3	11	3.6	2	1,974	180	0.6	360	†18	(*d*)	30	3.0	2.3	74	Special.
†6	8	1.3	2½	720	90	1.1	225	25	900	*e*55	3.0	*e*0.5–0.6	75	Average.[a]
†2	†7	3.5	4	500–400	71–57	1.4–1.8	289–228	......	480	†90	3.4	....	77	Average.
†3-6	12	2–4	6	600–1,200	50–100	1–2	300–600	19–30	600–1,200	36	......	....	80	Do.
3	8	2.7	6	450	56	1.7	336	12–15	470	56	......	....	......	Do.
4½	9	2	(*f*)	250	28	3.9	......	34	700	90	*8	*3	82	Do.
2	9	4.5	3	400	44	2.2	132	15–20	300	......	*3	....	83	Do.
4	9	2.2	5	680	75	1.3	375	18–20	300	*h* 50	......	*3	84	Do.
3	9	3	5	825	92	1.1	460	18–20	300	*h* 50	......	*3	84	Do.
5	9	1.8	4	700	77	1.3	308	*e* 22	......	†50	*3	*2.3	84	Do.
4	9	2.2	10	600	66	1.5	660	25–30	600	......	*5–4	*3	86	Do.
2	8	4	6	360	45	2.2	270	22	360	*60	......	*2.5	86	Do.
5	9	1.8	5	900	100	1.0	500	26	750	*33	*5	*3	86	Do.
2	6	3	6	400	70	1.5	420	18	400	60	......	2	92	Do.
2	6½	3.2	4	620	95	1.1	380	12	400	45	......	2	92	Do.
4	12½	3.1	3	1,350	195	0.5	588	23–28	(*i*)	(*)	3	2.8	97	Do.
......	8	......	......	....	....	......	......	45	......	......	4–2.8	3–1.7	98	Do.
4	11	2.7	4	760	70	1.5	280	23	480	40	......	2	100	Do.
2	9	4	10	250	28	3.6	280	19	*j* 600	40	......	*3	100	Do.
5	10	......	3	....	....	......	......	30–50	(*k*)	......	*6–2	*3	101	Do.
2	9	4.5	(*f*)	220	25	4	......	......	300	*80	......	*5	......	Do.
4	9.5	2.4	5	710	75	1.4	375	36	750	78	......	2.2	102	Do.
4	10	2.5	6	540	54	1.9	324	25	300	......	*2	....	......	Do.
4	9.5	2.1	5	520	55	1.8	275	30	600	58	......	....	......	Do.
4	9	2.2	10	800	89	1.1	890	18	400	50	*2	....	103	Do.
5	10	2	6	250	25	4	150	25–35	300	60	5–2	*2	......	Do.
5	9	1.8	......	900	100	1.0	......	26	1,500	......	......	3.3	......	Do.
4	9.5	2.1	3	800	84	1.2	252	21	600	33	3	2	......	Do.
7	10	1.4	......	360	36	3	......	20–30	†1,550	60	(†)	3	105	Do.
6	11	1.9	2	2,040	185	0.5	370	15–20	600	20	4	1.75–1.5	106	Do.
3	9	3	4	150	17	6	50	35	450	†58	4	2.5	107	Do.
3	9	3	6	405	45	2.2	270	19	900	52	2.1	1.5	108	Special.
4	10	2.5	4	1,500	150	0.7	600	25–30	400	50	6.7	5	......	Average.

d Patched every 180 heats.
e Average.
f Molder.
g "Up to 100."
h About.
i Patched every 50 heats.
j Patched every 60 heats.
k Patched every 100 heats.
l Special crucible.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions;

1. ROUND, PIT, NATURAL-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5	6				7			8	9
		In.	In.		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Lbs.
183	....	30	....	.....	†R. B.	....	....	....	.....	.....	.....	40-100	a 111
184	Mfg.	35	....	Volatile matter, 2.2; ash, 10.2; carbon, 87.2; sulphur, 0.4.	R. B.	....	....	....	25	75	.....	40-100	a 75
186	Job.	30	20	.....	88	4	5½	2½	.....	.....	.....	70	.....
188	Mfg.	32	16	Coal; 9.2 per cent ash; 13,000 B. t. u.; coke, 11.6 per cent ash; 0.9 per cent sulphur.	R. B.	....	....	....	70	30	.....	40	120
188	..do..	32	18		R. B.	....	....	....	70	30	.....	60	180
188	..do..	32	20		R. B.	....	....	....	70	30	.....	80	240
197	..do..	....	....	.....	88	2	10	....	.....	.....	.....	120	250
203	Roll.	42	19	48-hour.....	95	....	d 5	....	.....	.....	None.	.....	175
204	Mfg.	32	16	.....	†R. B.	....	....	....	.....	.....	.....	80	200
206	..do..	33	17	.....	†R. B.	....	....	....	10	80	10	40	a 138
206	..do..	33	19	.....	†R. B.	....	....	....	10	80	10	60, 70, 100	

2. SQUARE, PIT, NATURAL-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
32	Mfg.	32	14	70-hour Connellsville.....	R. B.	....	....	....	30	50	20	c 60	215
33	..do..	40	18	Connellsville.....	80	3	9	2	75	12	13	80, 100, 125	a 200
38	..do..	42	24	.....	88	2	10	....	.....	.....	.....	300	650
48	Job	....	....	Small stove size.....	84	6	5	5	45	55	.....	50	150
65	..do..	38	19	72-hour; volatile matter, 1.5; ash, 5.5; carbon, 93.5; sulphur, 0.65.	91	2½	2½	4	40	60	.....	80	240
70	Ref.	....	21	Crushed; 48-hour.....	85	5	5	5	Little.	.....	Mostly	300	666
72	Mfg.	36	24	By-product; 10 ash.....	R. B.	....	....	....	.....	.....	.....	60, 80	200
74	..do..	42	18	88 carbon; 9 ash; 1 sulphur.	88	2	10	....	60	40	.....	c 150, 175	375, 400
74	..do..	42	22	.....do.....	88	2	10	....	60	40	.....	c 200	650
74	..do..	48	24	.....do.....	88	2	10	....	60	40	.....	c 300	1,000
87	Job	48	20	12 ash; 1 volatile matter.	85	5	5	5	.....	80	20	150	375
87	..do..	60	24	.....do.....	85	5	5	5	.....	80	20	300	750
150	..do..	30	18	72-hour.....	R. B.	....	....	....	.....	.....	.....	100	225
201	..do..	48	22	72-hour Connellsville; natural draft, 3 ounces.	80	....	10	10	.....	.....	100	250	700

3. ROUND, PIT, NATURAL-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
11	Mfg.	48	17	72-hour Connellsville; 90 carbon; 13,000 B. t. u.; draft, 0.2 inch of water.	70	20	6	4	30	70	.....	60	150
20	Job	....	....	72-hour Connellsville; 88 carbon; 11.5 ash; and 48-hour Connellsville; 83.5 carbon; 14 ash.	Mn. Bz.	....	....	....	.....	.....	.....	250, 70	.....
66	Mfg.	....	....	Stove size.....	Y. B.	....	....	....	.....	.....	.....	50	100
78	..do..	....	....	Connellsville.....	79	16	5	....	10	90	.....	30-150	.....
123	Ref.	....	20	72-hour Connellsville..	73	21	3	3	None.	.....	Mostly	200	600
135	.....	40	18	By-product.....	68	32	....	....	.....	100	.....	75	100
147	Ref.	36	21	Half Connellsville coke; half anthracite coal.	80	17	1	2	.....	.....	Mostly	150	300
195	.....	24	14	72-hour.....	66, 80	33, 16	....	1, 4	.....	.....	.....	30	90

a Average. b Patched every 55 heats. c Two-thirds coke; one-third coal.

of furnaces and with various fuels—Continued.

† indicates that the notes on the reply number affect significance of figures so designated.]

FURNACES, MELTING LOW-ZINC ALLOYS—Continued.

Speed of melting: Heats per day.	Speed of melting: Hours per day.	Speed of melting: Hours per heat.	Speed of melting: Furnaces per tender.	Speed of melting: Metal per furnace per day.	Speed of melting: Metal per furnace per hour.	Speed of melting: Time per cwt. of metal.	Speed of melting: Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Melting loss: Gross.	Melting loss: Net.	Remarks: See notes on page —	Remarks: Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Lbs. coke.*	*Pct.*	*Pct.*		
3	10	3.3	6	333	33	3	200	31½	*b* 300	......	4	1.9	109	Average.
3	9	2	......	150	17	6	......	35	750	......	......	3	109	Do.
4	9	2.2	......	......	......	......	......	22	......	35	......	......	109	Do.
2	9	4.5	(†)	240	27	3.6	......			*c* 85				
2	9	4.5	(†)	360	40	2.5	......	*a* 10	300	*c* 57	†3.5	......	111	Do.
2	9	4.5	(†)	480	55	1.8	......			*c* 43				
2	8	4	3	500	63	1.6	190	25	......	......	2-1.5	......	114	Do.
4	9	2.2	†2½	700	77	1.3	192	32	400	40	1.7	......	115	Do.
4	11	2.7	8	800	73	1.4	584	18	700	66	3	......	116	Do.
5	8	1.6	5	690	86	1.2	......	1-20	500	39	6	†1.5	116	Do.

FURNACES MELTING LOW-ZINC ALLOYS.

3	8	2.6	5	645	80	1.2	400	22-30	550	42	5	......	80	Average.
2	10	5	6	400	40	2.5	240	14-18	(*f*)	†12	......	1-0.5	80	Do.
2	9½	4.7	......	1,300	135	0.6	......	16	270	......	......	7-5	80	Do.
3	8	2.7	3	450	56	1.7	168	25	470	50	......	*5	82	Do.
3	9	3	Over 3	720	80	1.2	......	26	720	35	*6	*4	84	Do.
6	24	4	1.5	*g* 4,000	166	0.6	......	13	300	30-50	......	8-7	85	Do.
3	9	3	6	600	67	1.5	400	†20	900	46	2.6	......	85	Do.
3-4	9½	3.1-2.4	......	1,125-1,800	110-190	0.8-0.7	......	17-19	500	33	(†)	(†)	86	Do.
2-3	9½	4.7-3.1	......	1,300-1,950	145-200	0.7-0.5	......	12-14	500	30	(†)	(†)	86	Do.
2	9½	4.7	......	2,000	210	0.5	......	22	450	25	(†)	(†)	86	Do.
2	9	4.5	3	750	85	1.2	255	25	210	45	*2	......	95	Do.
2	9	4.5	3	1,500	165	0.6	495	18	210	45	*2	......	95	Do.
3	8	2.6	2	450	56	1.8	112	10-22	(*h*)	41	4	......	......	Do.
2½	10	4	3½	1,750	175	0.6	612	18	375	35	2.8	......	114	Do.

FURNACES MELTING HIGH-ZINC ALLOYS.

2	10	5	4	300	29	3.3	116	16	1,800	40	2.4	......	74	Average.
......	11½	......	3	......	......	......	......	......	......	50-60	†4.5	3	77	Do.
4	9	2.2	4	400	44	2.2	176	35-45	400	40	......	......	......	Do.
3	7½	2.5	4	......	......	......	......	13-15	225-900	63	13-3	5-3	86	Do.
2	10	5	2	1,200	120	0.8	240	20	300	42	3	1.5	102	Do.
4	11	2.7	4	400	36	2.9	204	36-48	*i* 600	25-33	4	2	103	Do.
4	10	2.5	2	1,560	156	0.6	312	24	400	30	10	8	103	Do.
2	9	4.5	......	180	20	5	......	18-30	450	55	†1(?)	†0.1(?)	114	Do.

d And German silver.
e Special crucible.
f Patched every 50 heats.
g In operation 24 hours a day.
h Patched every 21 heats.
i Patched every 100 heats.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions;

4. SQUARE, PIT, NATURAL-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5	6				7			8	9
		In.	In.		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Lbs.
36	Roll	....	14	By-product; 1.3 volatile matter; 88 carbon; 10.7 ash; draft, 1½ inches of water.	65	35	....	....	55	....	45	60	175
74	Mfg.	....	....	....	(†)				....	....	....	....	....
83	..do..	24	22	72-hour Connellsville; moisture and volatile matter, 1.2; ash, 11.3; carbon, 87.5; sulphur, 0.7; phosphorus, 0.15; two-thirds coke, one-third coal used.	(†)				67	30	3	150	350
c87	.....	....	....	....	{Mn. Bz. }	....	....	....	....	....	....	....	....

5. ROUND, PIT, FORCED-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
46	Mfg.	30	20	By-product or Connellsville; forced draft, 10-ounce pressure.	(†)				....	....	....	60	150
85	..do..	48	20	72-hour........	R. B.	....	....	....	....	100	....	80	225
94	..do..	....	....	By-product egg; forced draft, 20-ounce pressure.	83	13	....	4	52	....	....	60	156

6. SQUARE, PIT, FORCED-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
60	......	54	14	Two-thirds coke, one-third coal.	80	18	....	2	......	Mostly.	None.	e 35	150

7. ROUND, PIT, NATURAL-DRAFT, COAL

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
23	Mfg.	39	18	Egg anthracite........	R. B.	....	....	....	....	....	......	90	260
26	..do..	....	....	....	R. B.	....	....	....	33	50	17	50	150
29	..do..	....	14	....	R. B.	....	....	....	....	....	....	e 14	45
49	Job.	....	....	....	....	....	....	....	....	....	....	....	....
59	..do..	....	....	....	....	....	....	....	....	....	....	20	60
60	Mfg.	30	25	Egg........	84	6	7	3	....	....	None.	50, 60	120
61	..do..	30	12	Stove; moisture and volatile matter, 8; ash, 12; carbon, 82; sulphur, 1; 13,000 B. t. u.	86	7	5	2	......	Mostly.	....	25	75
61	..do..	36	16	.....do........	86	7	5	2	......	...do..	....	50	150
71	Job.	35	16	Egg........	83	10	4	3	None.	Some.	Some.	h 85	258
80	..do..	31	17	.....do........	R. B.	....	....	....	....	100	....	60	175
89	Ref. and job.	....	....	....	R. B.	....	....	....	....	....	Mostly.	30-80	100
105	Job.	....	16	....	R. B.	....	....	....	....	....	....	25	75
107	Job.	24	13	Egg........	75	10	10	5	None.	....	....	20	60
110	..do..	31	16	....	88	3	8	1	55	30	25	50-80	....
111	Mfg.	32	14	Egg........	R. B.	....	....	....	None.	....	....	35	100

a Less than 4.5.
b Less than 3. See notes on Reply 83.
c See subdivision 2, Reply No. 87.
d Patched every 100 heats.
e Special crucible.
f Patched every 200 heats.
g Patched every 24 heats.
h About.

of furnaces and with various fuels—Continued.

† indicates that the notes on the reply number affect significance of figures so designated.]

FURNACES MELTING HIGH-ZINC ALLOYS.

Speed of melting.										Fuel consumption per cwt. of metal melted.	Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.		Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Lbs. coke.*	*Pct.*	*Pct.*		
5	7	1.4	†3	875	125	0.8	375	35	1,100	24	4	2	80	Average.
......	......	......	......	......	......	......	......	......	......	......	†3–2	†2–1.5	86	Do.
1	6	6	8	350	58	1.7	464	15	150	133	(a)	(b)	92	Do.
......	......	......	......	......	......	......	......	......	......	50	10–7	......	94	Do.

FURNACES MELTING LOW-ZINC ALLOYS.

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
†4	9	2.2	5	600	67	1.5	330	25	*d* 200	50	†5–4	......	81	Average.
4	8	2	4	900	113	0.9	450	20–35	480	44	......	2.5	93	Do.
6	9	1.5	3	936	104	1	310	38	900	53	......	1.2	96	Do.

FURNACES MELTING HIGH-ZINC ALLOYS.

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
9	11	1.2	4	1,200	109	0.9	436	22	(*f*)	60	......	......	84	Average.

FURNACES MELTING LOW-ZINC ALLOYS.

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
4	10	2.5	†8	1,040	104	0.9	†832	22	*g* 600	29	1.5	......	78	Average.
3	9	3	8	450	......	......	......	24–35	900	50	4	2.3	79	Do.
6	11	1.9	12	270	25	4	300	23	†9,000	......	......	......	79	Do.
4	9	2.2	8	......	......	......	......	30–40	......	(†)	(†)	......	......	Do.
4	10	2.5	4	240	24	4	96	20–40	300	......	......	......	......	Do.
5	11	2.2	*h* 10	600	55	1.9	550	30	*i*2,250	46	......	......	84	Do.
4	10	2.5	9	300	30	3.3	270	32	......	63	†5.6	......	84	Do.
4	10	2.5	7½	600	60	1.7	450	28	......	38	†5.6	......	84	Do.
3	12	4	5	775	65	1.5	325	20–24	*k* 450	42	3–2.5	2.5–2	85	Do.
2	8	4	(*l*)	350	45	2.3	......	20–30	900	100	......	2	90	Do.
2	9	4.5	6	200	20	4.5	120	25	150	75	†8	5	95	Do.
3	9	3	(*n*)	225	25	4	......	......	450	44	......	......	......	Do.
4	9	2.2	6	240	27	3.8	162	26	(*o*)	......	*p* 10–6	......	99	Do.
5	10	2	4	*m* 600	60	1.7	240	*m* 16	......	30	10–5	1.3	100	Do.
4	10	2.5	4	400	40	2.5	160	48	......	40	......	*4	......	Do.

i Patched every 30 heats.
k Patched every 18 heats.
f Over 3.
m Average.
n Molder.
o Patched every 100 heats.
p Estimated. See notes on reply 107.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions;

7. ROUND, PIT, NATURAL-DRAFT, COAL

Reply No.	Nature of plant.	Height or shape of furnace	Diameter or inside length of furnace.	Fuel and air supply.	Analysis of charge.				Composition of charge.			Crucible maker's No.	Weight of charge.
					Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.		
1	2	3	4	5	6				7			8	9
		In	In		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Lbs.
116	Mfg.	....	....	....	....	....	....	....	....	100	....	12	27½
121	....	....	....	....	....	....	....	....	....	....	....	40, 60, 80	....
128	Job.	....	22–25	Egg	R. B.	....	....	....	....	....	None.	20–30	67
130	....	....	....	....	83	9	4	5	25	50	25	45–60	111
131	Mfg.	30	22	Egg and stove	87	4⅓	4⅓	4⅓	35	40	25	80	270
132	..do..	30	17	....	R. B.	....	....	....	....	100	....	60–80	213
138	..do..	....	18	....	R. B.	....	....	....	....	....	....	90	....
139	..do..	....	....	....	85	5	5	5	....	70	30	60	175
143	..do..	30	16	Egg	R. B.	....	....	....	50	Some	Some.	30	50
155	..do..	26	15	....	R. B.	....	....	....	40	35	25	20	60
158	....	....	....	....	R. B.	....	....	....	....	60	40	60	175
166	....	36	18	....	R. B.	....	....	....	....	100	....	16	50
171	Job.	32	18	Stove coal and a little by-product coke.	80	6	9	5	....	....	....	125	375
172	Mfg.	30	16	....	R. B.	....	....	....	....	....	....	[e] 80	270

8. SQUARE, PIT, NATURAL-DRAFT, COAL

Reply No.	Nature of plant.	Height or shape of furnace	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
79	Mfg.	43	22½	Egg; volatile matter, 7.2; ash, 10.6; 12,750 B. t. u.	90	7	3	....	100	....	....	200	555
79	..do..	36	18½	..do.	90	7	3	....	100	....	....	80	242
109	....	36	16	Coal and charcoal	Bz.	....	....	....	....	Mostly	....	18	50
199	....	23	13½	....	88	....	12	....	....	....	....	20	47

9. ROUND, PIT, NATURAL-DRAFT, COAL

Reply No.	Nature of plant.	Height or shape of furnace	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
21	Ref.	36	21	....	Y. B.	....	....	....	....	....	Mostly	200	500
118	Mfg.	24	12	....	Y. B.	....	....	....	....	....	....	30	90
122	....	....	....	....	80	15	5	....	....	....	....	30, 35	[b] 83
127	Mfg.	....	....	....	Y. B.	....	....	....	....	....	Much.	40–60	[b] 120
149	..do..	29	16	....	66	27	....	7	....	....	....	40, 50	[b] 100
165	..do..	36	16	Egg	Y. B.	....	....	....	....	....	....	45	100
181	..do..	34	18	..do.	Y. B.	....	....	....	....	80	20	60	170
193	..do..	28	14	Draft, 0.8 inch of water	62	34	....	4	....	65	35	35	85

[a] Patched every 36 heats.
[b] Patched every 20 heats.
[c] "Two scuttles."
[d] Molder.
[e] Special crucible.

of furnaces and with various fuels—Continued.

† indicates that the notes on the reply number affect significance of figures so designated.]

FURNACES MELTING LOW-ZINC ALLOYS—Continued.

Speed of melting.											Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Lbs. coke.*	*Pct.*	*Pct.*		
......	......	......	......	......	......	......	......	......	......	73	......	......	......	Average.
4 on 40 3 on 60 2 on 80	10	......	......	......	......	......	......	20–30	900	......	......	......	101	Do.
3	9½	3.2	8	200	21	4.9	168	†28	*a* 900	100	......	5–2	102	Do.
3	9	3	8	342	28	2.9	304	20–30	450	44	5	4.75	......	Do.
3	10	3.3	10	710	71	1.4	710	20	*a* 900	61	......	......	......	Do.
3	11	3.7	12	640	58	1.7	800	18–23	900	62	......	*2–1	102	Do.
2	10	5	7	......	......	......	......	31	......	......	6	......	......	Do.
3	9½	3.2	7	525	55	1.8	375	20	*b* 900	45	......	*3	103	Do.
3	9	3	......	150	17	6	......	30	300	(*c*)	10	5	103	Do.
4	9	2.2	(*d*)	240	27	3.8	......	35–40	700	40	4.1	0.8	104	Do.
3	11	3.7	6	525	48	2	288	18–24	......	†50	......	3.3	104	Do.
6	9½	1.6	9	300	31	3.2	280	......	{ 450–900 }	60	3.5	......	107	Do.
2	7½	3.8	6	750	100	1	600	20	600	{ 24 coal, 3⅓ coke. }	4	2.5	107	Do.
4	12	3	10	1,080	90	1.1	900	20	......	30	......	2	107	Do.

FURNACES MELTING LOW-ZINC ALLOYS.

2	7	3.5	4	1,110	160	0.6	640	12	600	†35	0.61	......	87	Special.
3	7	2.3	5	725	103	1	515	16	750	†28	.62	......	87	Do.
3	7	2.3	......	150	21	4.9	......	35	......	(*f*)	10	8–7	100	Average.
3	6	2	(*d*)	170	28	3.5	......	30	......	44	......	5–1	114	Do.

FURNACES MELTING HIGH-ZINC ALLOYS.

2	9	4.5	4	1,000	111	0.9	444	25–35	......	*25	......	......	78	Average.
2	8	4	(*g*)	180	23	4.2	......	......	200	*80	......	......	101	Do.
3	9	3	2	250	28	3.6	56	10–15	900	......	4–2	3–2	102	Do.
3	9	3	5	360	40	2.5	200	40–50	450	70	4	......	......	Do.
3	10	3.3	7	300	30	3.3	210	45	{ 450–900 }	100	......	*3	104	Do.
6	10	1.7	7	600	60	1.7	420	29	900	33	15–10	5–3	107	Do.
4	8	2	9	680	85	1.2	735	17	*i* 2,400	†100	3	......	109	Do.
5	10	2	8	425	43	2.3	344	27½	440	35	12	4	113	Do.

f Over 66.
g Over 3.

h Average.
i Patched every 25 heats.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions;

10. SQUARE-PIT, NATURAL-DRAFT, COAL

Reply No.	Nature of plant.	Height or shape of furnace	Diameter or inside length of furnace.	Fuel and air supply.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5	6				7			8	9
		In.	*In.*		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		*Lbs.*
17	Roll	....	16	....	65	35	....	....	35	....	65	60	160
95	..do..	33	15	Egg coal; 14,000 B. t. u..	66	34	....	....	30	....	70	70	200
140	..do..	39	16½	Egg	66	34	....	....	60	13	27	80, 90	220
141	..do..	....	45	90 per cent of coal, 10 per cent of coke; draft, 1 inch of water.	70	30	....	....	60	40	....	70	190
151	..do..	30	15	Egg......................	66	34	....	....	66	34	....	70	200
189	..do..	....	16	Egg; 13,000 B. t. u.......	65	35	....	....	75	25	....	....	240
189	..do..	....	18	.....do...................	65	35	....	....	40	60	....	....	450
192	..do..	....	....	Coal and little coke......	65	35	....	....	....	....	....	80	....
194	..do..	48	16	Egg......................	65	35	....	....	....	....	....	65, 70	180
200	..do..	33	16	Coal and little coke......	[b] 65	35	....	....	....	....	....	60	180
				11. ROUND, PIT, FORCED-DRAFT, COAL									
4	Mfg.	23	13	Range coal; forced draft, 1¼-ounce pressure.	R. B.	....	....	....	....	....	....	30	100
4	..do..	25	15	.....do...................	R. B.	....	....	....	....	....	....	50	....
4	..do..	34½	22	.....do...................	R. B.	....	....	....	....	....	....	100	....
12	..do..	34	16½	Forced draft, 24-ounce pressure.	R. B.	....	....	....	....	100	....	40, 60, 80	[c] 125
22	..do..	30	†16	1-ounce pressure..........	R. B.	....	....	....	....	....	....	100	240
56	..do..	24	12	Nut and range coal; 30-pound (?) pressure.	R. B.	....	....	....	....	....	....	40	100
57	Job.	30	[a] 18	Range coal; "fan pressure."	R. B.	....	....	....	....	....	....	45, 50	[c] 100
115	Mfg.	24	16	....	R. B	....	....	....	....	....	....	20	60
185	..do..	34	16	9-ounce pressure..........	R. B.	....	....	....	....	....	....	80	225
				12. ROUND, PIT, FORCED-DRAFT, COAL									
24	Mfg.	42	22	Coal, 12,470 B. t. u., 13 per cent of ash; and coke, 11.4 per cent of ash,† 3-ounce pressure.	Mn. Bz.	....	....	....	60	40	....	200	600
62	..do..	30	17	14,600 B. t. u............	72	26	....	2	20	80	....	60, 70	....
99	..do..	....	14	10-ounce pressure.........	79	13½	3½	3	....	....	....	60	142
147	..do..	24	16	Stove size................	Y. B.	....	....	....	....	80	20	50	142

[a] Patched every 100 heats. [b] And some German silver. [c] Average.

of furnaces and with various fuels—Continued.

† indicates that the notes on the reply number affect significance of figures so designated.]

FURNACES MELTING HIGH-ZINC ALLOYS.

Speed of melting.										Fuel consumption per cwt. of metal melted.	Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.		Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Lbs. coke.*	*Pct.*	*Pct.*		
4	9	2.2	3¼	640	70	1.4	231	......	......	39	3.5	....	76	Average.
5	10	2	3¼	1,009	100	1	333	30	*a* 500	33	3	2	97	Do.
5	9½	1.9	3⅓	1,100	114	0.9	380	19–32	750	33	4	2	103	Do.
8	10	1.3	1⅔	1,520	152	0.6	252	25	1,000	33–37	3.67	2.22	103	Do.
5	10	2	3⅓	1,000	100	1	333	30	......	30	3	2.5	104	Do.
5	9	1.8	3⅓	1,200	133	0.7	430	40	960	35	1.75	1.25	112	Do.
5	9	1.8	2½	2,250	250	0.4	625	40	960	33	1.75	1.25	112	Do.
......	......	......	......	......	......	......	......	35	.....	30	3	1.5	113	Do.
5	9½	1.9	2⅔	900	95	1	255	55	......	28	......	2	113	Do.
4	10	2.5	3⅓	649	64	1.5	213	30	600	50.3 Coal, 11.2 Coke	6.5	....	114	Do.
FURNACES MELTING LOW-ZINC ALLOYS.														
4	9	2.2	6	400	44	2.1	264	40	400	29	......	0.5	72	Average.
......	......	......	......	......	......	......	......	35	400	26	......	0.5	72	Do.
......	......	......	......	......	......	......	......	23	400	†27.5	......	0.5	72	Do.
5	8½	1.7	10	625	75	1.3	750	18–23	480	119	*3	....	74	Do.
4	10	2.5	3½	1,160	116	0.9	416	22	*d* 600	30	4–5	3	78	Do.
3	9	3	6	300	33	3	198	35	900	39	6.7	*5	83	Do.
3	9	3	5	300	33	3	165	30	900	30	*5	....	......	Do.
2	7½	3.7	......	120	16	6.3	......	45	300	125	......	......	100	Do.
3	10	3.3	5	675	68	1.5	340	10–18	450	52	......	.....	109	Do.
FURNACES MELTING HIGH-ZINC ALLOYS.														
1	5	5	4	600	120	0.8	480	†15	......	(*e*)	5	....	78	Average.
4–5	10	2–2.2	7	*c* 845	85	*c* 1.2	*c* 595	25	330	28.5	3	1	84	Do.
3	10	3.3	9	425	43	2.3	390	23	600	41	*3.5	*3	97	Do.
4	10	2.5	7	580	57	1.9	400	32	600	50	5	3.5	.....	Do.

d Patched every 4 heats.

e 40 pounds of coal and 10 pounds of coke.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions;

13. ROUND, TILTING, FORCED-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Analysis of charge.				Composition of charge.			Crucible maker's No.	Weight of charge.
					Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.		
1	2	3	4	5	6				7			8	9
		In	*In*		*Pct.*	*Pct.*	*Pct.*	*Pct*	*Pct.*	*Pct.*	*Pct.*		*Lbs.*
6	Job and mfg	30	2[illegible]	48-hour; volatile matter, 1; ash, 11; carbon, 88; sulphur, 0.9; 12,740 B. t. u.; forced draft, 2 ounces.	Pb. Bz.	....	....	....	......	......	......	200	600
26	Mfg.	....	....	....	R. B.	....	....	....	......	......	......	......	500
63	..do..	....	....	1-ounce forced draft.....	88	3	5	4	......	10	......	200	600
70	..do..	30	26	72-hour; volatile matter, 2.5; sulphur, 0.9; 12,750 B. t. u.	89	2	6½	2½	100	......	......	225	600
101	..do..	30	26	Connellsville; forced draft, 1 ounce.	80	10	5	5	......	......	......	225	700
112	..do..	....	....	72-hour..................	R. B	....	....	....	......	......	......	......	450
152	..do..	29	23	Connellsville; forced draft, 0.5 to 1.5 ounces.	90	1	8	1	45	35	20	275	450
170	..do..	30	20	72-hour..................	R. B	....	....	....	......	......	......	......	130
205	......	....	....	(†)......................	88	2	10	....	50	50	......	......	400

14. ROUND, TILTING, FORCED-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
41	Mfg.	....	....	By-product; 2-ounce forced draft.	65	34	....	1	......	80	20	225	600
90	..do..	30	19	72-hour Connellsville; forced draft, 1.5 to 2 ounces.	66	34	....	....	......	75	25	Tall	410
154	..do..	....	....	Forced draft, 2 pounds..	66	32½	....	1½	None	......	Some.	225	500
180	..do..	....	....	72-hour Connellsville....	Mn. Bz.	....	....	....	......	100	......	......	450

15. SQUARE, TILTING, FORCED-DRAFT, COKE

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
79	Mfg. Roll.	36	21	Connellsville; forced draft, 3 ounces.	65	32	....	....	33	......	67	......	666

a Patched every 15 heats. *b* Patched every 18 heats.

of furnaces and with various fuels—Continued.

† indicates that the notes on the reply number affect significance of figures so designated.]

FURNACES MELTING LOW-ZINC ALLOYS.

Speed of melting.											Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Gals. oil.*	*Pct.*	*Pct.*		
10	10	1	1	6,000	600	0.17	600	†40	1,200	17.5	5.5	2	72	Average.
6	9	1.5	......	3,000	330	.35	......	50-60	......	13-16.5	4	2.2	79	Do.
6	10	1.7	2	3,600	360	.28	720	16	900-1,200	17.3	2.2	2	84	Do.
5	7½	1.5	1	3,000	400	.25	400	21	......	21	0.64	....	87	Special.
2	4	2	4	....	350	.29	1,400	28	1,200	36	4-1.7	3-1.4	98	Average.
3	12	4	2	1,350	135	.75	270	20-25	(*a*)	27	1	....	....	Do.
†3	9	3	4	2,250	250	.40	1,000	12	......	40	†0.51	†1.86	104	Do.
6	11	1.8	2	2,580	235	.43	470	†58	†450	22	5	2	107	Do.
6	7	1.2	......	....	....	......	......	40	......	20	1.1	....	116	Special.

FURNACES MELTING HIGH-ZINC ALLOYS.

4	10	2.5	3	2,400	240	0.41	720	......	......	25	......	4	81	Average.
6	10	1.7	1	2,640	264	.36	264	†45	*b*1,000	15	......	4.9	95	Do.
4	10	2.5	1	2,000	200	.50	200	20	300	†7.5	5	3	104	Do.
4	9	2.2	2	1,800	200	.50	400	†40	600	20	3	....	109	Do.

FURNACES MELTING HIGH-ZINC ALLOYS.

6	8	1.3	2	4,000	500	0.20	1,000	3-48	(*c*)	15	2.8	0.9	87	Average.

c Patched every 12 to 15 heats.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions

16. ROUND, PIT, OIL FURNACES, WITH LOW

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply. Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5a	5b	5c	5d	6				7			8	9
		In.	In.		Per lb.	Oz.	Lbs.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Lbs.
3	Mfg.	36	20	0.88	19,000	6	40	83½	8	4½	4	50	40	10	70, 80	a 220
14	Ref.	27	23	.85	......	6	25	85	5	4	6	......	......	Mostly	b 250	650
40	......	36	{16-28}	......	......	18	15	85	5	5	5	......	......	......	40-200	......
45	Job.	....	....	.88	......	10	35	82	....	4	14	......	......	......	80	244
52	Mfg.	....	....	.89	(†)	......	......	81	10	3	3	15	75	10	45, 70	a 146
54	..do..	....	....	......	......	18	......	R. B.	....	....	....	......	......	......	60	160
75	..do.	26	16	......	......	10	25	84	(c)	4	(c)	......	......	......	50	150
102	Job.	....	....	......	......	2-5	35	85	5	5	5	Some.	Some	Some.	80, 125	......
103	..do..	....	(†)	.89	19,500	......	......	R. B.	....	....	....	70	30	......	80	220
134	......	32	18	(†)	(†)	(†)	(†)	(†)	(†)	(†)	(†)	12	88	......	60	180
157	......	28	18	.84	......	16	10	85	5	5	5	......	......	......	70	200
186	......	....	....	......	......	......	......	84	4	5½	5½	......	......	......	70	200
188	Mfg.	34	24	.86	19,000	8	60	R. B.	....	....	....	......	55	45	175	a 336
188	..do..	30	22	.86	19,000	8	60	R. B.	....	....	....	......	55	45	125	a 336
17. SQUARE, PIT, OIL FURNACES, WITH LOW																
106	Mfg.	20	20	......	......	Low	30	Bz	....	....	....	......	......	......	50	150
150	..do..	22	16	0.86	......	8-12	17	Bz	....	....	....	......	100	......	100	275
18. ROUND, PIT, OIL FURNACES, WITH LOW																
1	Mfg.	20	16	0.87	......	16	15	60	35	....	5	20	60	20	60	180
20	Job.	....	....	.86	......	16	30	{Mn. Bz.}	....	....	....	50	50	......	......	......
93	Mfg.	16	15	......	......	16	30	74	11	3	5	......	......	......	50, 60	a 140
93	..do..	16	15	......	......	16	30	74	11	3	5	......	......	......	80	170
94	..do..	....	....	......	......	20	20	83	13	....	4	52	......	......	60	175
146	Job.	....	....	.85	......	20	15	67	29	....	4	None.	Mostly.	Some	70	180
181	Mfg.	....	....	......	......	6	40	Y. B.	....	....	....	......	80	20	60	170
189	Ref.	....	....	......	......	......	......	65	35	....	....	......	......	100	......	250, 400
19. ROUND, PIT OIL FURNACES, WITH HIGH																
						Lbs.										
8	Job.	....	....	0.88	19,250	......	35	85	5	5	5	75	25	......	80	200
44	......	....	....	......	......	......	......	85	7½	7½	....	......	......	......	70, 100	a 200
70	Mfg.	30	16	.91	......	4	(d)	82	6	6	6	......	......	......	80	208
86	..do..	27	16	.95	†18,800	......	20	R. B. Bz.	....	....	....	......	......	......	100	270
88	..do.	24	18½	......	......	5	4½	R. B.	....	....	....	......	......	......	60	175
136	..do..	....	....	......	......	†4	80	R. B.	....	....	....	......	......	Some.	60	170

a Average.
b Special crucible.
c 21 heats with No. 45 crucible and 18 heats with No. 70 crucible.
d Patched daily.

of furnaces and with various fuels—Continued.

† indicates that the notes on the reply number affect significance of figures so designated.]

PRESSURE AIR, MELTING LOW-ZINC ALLOYS.

Speed of melting.											Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Gals. oil.*	*Pct.*	*Pct.*		
9	9	1	4	2,000	222	0.45	888	40	1,350	†2.2	1.5	1.0	70	Average.
†3	11	3.6	3	†1,950	†180	0.6	†540	17	480	2.8	3.7	....	74	Special
6	8	1.3	2-5	....	....	....	....	10-30	900	3	.....	5	81	Average.
9	10½	1.2	6	2,200	210	0.5	1,320	36	c 700	(†)	6	....	81	Do.
4	7	1.7	4	575	82	1.2	328	(c)	d2,490	3	4.7	3.7	82	Do.
7.5	11½	1.6	......	1,400	120	0.8	......	35	2,200	......	......	*2.5	83	Do.
6	9	1.5	......	900	100	1	......	25-30	900	3	*5-4	*3	86	Do
7	9	1.3	4	....	....	....	......	20-35	450	3.5	7-3	5-2	98	Do.
4.5	8	1.9	4	980	120	0.8	480	18	c4,800	2.3	......	....	98	Do.
(†)	(†)	1	......	....	180	0.55	......	20	......	(†)	6	....	102	Do.
6	10	1.7	5	1,200	120	0.8	600	43	1,800	(†)	......	....	105	Do.
6	9	1.5	......	1,200	133	0.75	......	22	......	2.3	......	....	109	Do.
2.4	4.2	1.7	(†)	....	200	0.5	......	a 15	375	3.5	†3.5	....	111	Do.
2.4	4.2	.....	(†)	....	....	....	......	....	......	......	......	....	111	Do.

PRESSURE AIR, MELTING LOW-ZINC ALLOYS.

3	10	3.3	3	450	45	2.2	135	23	......	†8	......	(f)	98	Average.
3	9	3	5	850	95	1	475	20	......	7.8	3	1.5	104	Do.

PRESSURE AIR, MELTING HIGH-ZINC ALLOYS.

8	10	1.2	4	1,440	144	0.7	576	28	......	1.8	2	0.75?	70	Average.
......	.....	....	......	....	....	......	......	....	......	......	4.7	....	77	Special.
7	10	1.4	5	980	98	1	490	33	......	3.5	6	5	96	Average.
6	10	1.7	5	1,020	102	1	510	33	......	3.5	6	5	96	Do.
9	9	1	3	1,575	158	0.6	574	50	1,050	3	......	1.5	96	Do.
5	10	2	3½	900	90	1.1	305	25-28	(g)	(†)	......	....	104	Do.
......	.....	....	......	....	....	......	26-30	....	......	3.2	1.7	....	109	Do.
4	10	2.5	5	{1,000, 1,600	100, 160	}1-0.6	51, 49	....	400	......	5	....	112	Do.

PRESSURE AIR, MELTING LOW-ZINC ALLOYS.

7	10	1.4	8	1,400	140	0.7	1,120	23	780	2.2	1.6	....	73	Special.
3	9	3	3	600	67	1.3	200	6-12	(h)	3.3	6	....	81	Average.
4	9½	2.4	5	836	90	1.1	450	19	600	2.3	......	4	82	Do.
3	8	2.7	2	810	100	1	200	20	......	*2	......	(j)	93	Do.
7½	9½	1.3	4	1,320	140	.7	560	35-82	1,900	2.2	5.5	....	95	Do.
6	10	1.7	5	1,000	100	1	500	42	......	3	......	....	103	Do.

e Some.
f Less than 1 per cent.
g Patched every 60 heats.
h Patched every 18 heats.
i Gravity.
j Estimated to be less than 2 per cent.

Details of brass-melting practice in various types

[† Designates estimated results rather than results based on average running conditions

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply. Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5a	5b	5c	5d	6				7			8	9
20. ROUND, PIT OIL FURNACES, WITH HIGH																
		In.	In.		Per lb.	Oz.	Lbs.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Lbs.
25	......	18	15	0.86	18,000	16	29	Mn. Bz.	....	....	....	25	50	25	20-60	a 125
100	Mfg	24	17	.88	......	15	1	Y. B.	....	....	....	....	....	....	45	130
124	..do..	....	....	.95	......	20	10	Y. B.	....	....	....	33	67	....	45, 50	a 1[illegible]
160	..do..	24	20	.88	......	10	20	75	15	5	5	30	45	25	125	350
21. PIT, OIL FURNACES, WITH HIGH-PRESSURE AIR AND																
58	.....	(e)	(e)	......	......	6	(f)	R. B.	....	....	....	....	100	.....	35	(g)
22. PIT, OIL FURNACES, WITH HIGH-PRESSURE AIR AND																
5	......	(i)	(i)	0.80	......	7½	6½	73½	22	1½	3	20	75	5	25	(k)
23. PIT, NATURAL-DRAFT, OIL FURNACES, WITH																
198	......	(†)	(†)	0.85	......	(†)	(†)	R. B.	...	....	....	33	42	25	40, 60, 100	....
24. ROUND, PIT, NATURAL-GAS FUR																
					Per cu. ft.	Oz.	Oz.									
15	Mfg.	....	....	......	1,059	20	4½	84½	4½	8½	2½	20	50	......	60	180
120	..do..	26	34	......	......	......	......	85	5	5	5	35	45	25	40, 50, 60	a 155
178	......	....	....	......	......	......	......	......	....	....	....	....	....	....	20, 25	a 48
201	Job.	48	22	......	1,000	4	7	80	....	10	10	....	....	100	200	650
25. ROUND, PIT, CITY-GAS FURNACES																
12	Mfg	35	17	......	590	24	4	85	5	5	5	....	....	None.	60, 80	a 200
94	..do..	....	....	......	650	20	2	83	13	....	4	37	Some.	Some.	70	185
108	......	....	....	......	625	†48	6	88	....	....	....	....	....	....	50	150
26. ROUND, PIT, PRODUCER-GAS FUR																
164	Mfg	....	....	......	120	†9	3	R. B.	....	....	....	50	Some.	Some.	70	200

[a] Average.
[b] Patched every 70 heats.
[c] Patched every 90 heats.
[d] Patched daily.
[e] Pit dimensions, 10 by 21 inches.
[f] Gravity.
[g] 108 pounds per crucible.
[h] Results based on use of two crucibles per furnace.

of furnaces and with various fuels—Continued.

† indicates that notes on the reply number affect significance of figures so designated.]

PRESSURE AIR, MELTING HIGH-ZINC ALLOYS.

Speed of melting.								Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.				Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Gals. oil.*	*Pct.*	*Pct.*		
6	8	1.3	4	750	94	1.1	375	30	2,400	......	10	....	79	Average.
6	9	1.5	4	780	85	1.2	340	45-50	b1,800	*5	4	3.5	97	Do.
......	......	......	......	....	....	......	......	†12-30	(c)	......	*10	*5	102	Do.
3	10	3.3	3	1,050	105	0.95	315	17-20	d 450	2	6-4	3-2	105	Do.
SEVERAL CRUCIBLES, MELTING LOW-ZINC ALLOYS.														
3	8	2.7	......	648	81	1.2	......	15	150	*2.8	1.5	....	83	(k)
SEVERAL CRUCIBLES, MELTING HIGH-ZINC ALLOYS.														
3	10	3.3	1	1,680	168	0.6	168	18½	90	5.6	......	3.8	72	(l)
SEVERAL CRUCIBLES, MELTING LOW-ZINC ALLOYS.														
4	11	2.7	2	3,000-4,000	273-382	0.33-0.27	546-764	a 15	m1,500	*1	2.1	2.05	114	(n)
NACES MELTING LOW-ZINC ALLOYS.														
										Cu. ft. gas.				
7	9	1.3	4	1,280	142	0.7	568	55	.....	310	......	1.4	74	Average.
2⅓	8	3.5	3	360	45	2.2	135	a 11	175	......	4.3	....	101	Do.
3	6	2	......	....	24	4	1,040	22-32	......	......	......	....	108	Do.
3½	8	2.3	4	2,275	260	.4	......	15	800	231	2.25	....	114	Special.
MELTING LOW-ZINC ALLOYS.														
5	7	1.4	......	1,000	142	0.7	......	25	......	650	.....	2.3	74	Average.
9	9	1	3	1,665	185	.5	555	....	......	382	5.7	2.2	96	Do.
8	10	1.2	8	1,200	120	.8	960	45-60	900	256	......	1.25 1.50	99	(o)
NACES MELTING LOW-ZINC ALLOYS.														
7	10	1.4	8	1,400	140	0.7	1,120	†20	p 525	3,500	......	†1-0.75	106	Special.

i Pit dimensions 40 by 27 inches by 30 inches high.
k 60 pounds per crucible.
l Results based on use of seven crucibles per furnace.
m Patched every 300 heats.
n Results based on six crucibles per furnace.
o Three burners per furnace.
p Patched every 40 heats.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions.

27. ROUND, TILTING, NATURAL-GAS

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply. Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5a	5b	5c	5d	6				7			8	9
		In.	In.		Per cu. ft.	Oz.	Lbs.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Lbs.
7	Job.	....	....	......	......	......	......	R. B.[a]	....	....	....	....	....	....	125	300
15	Mfg.	....	....	......	1,059	20	4½	87	5½	5½	1½	....	100	....	125	305
55	..do.	....	....	......	940	......	8	R. B.	....	....	....	....	....	....	125, 275	....
112	..do..	....	....	......	......	......	......	R. B.	....	....	....	....	....	....	....	450
145	..do..	22	16½	......	......	16	6	85	4½	6½	4	15	50	35	125	....
167	..do..	28	17½	......	......	......	......	R. B.	....	....	....	....	....	....	70	180

28. ROUND, TILTING, OIL FURNACES, WITH LOW-

					Per lb											
10	Mfg.	24	24	0.88	19,000	10	30	86	6	3	5	....	....	....	([b])	250
13	..do..	26	17	.87	19,500	10	¾	64	10	....	(†)	32	68	....	125	240
28	..do..	....	....	......	......	18	(†)	85	5	5	5	20	60	20	275	500
34	..do..	28	20	......	......	19	18	85	5	5	5	....	....	....	275	500
54	..do..	....	....	......	......	18	......	R. B.	....	....	....	....	....	....	125	350
63	..do..	....	21	......	......	12	20	88	3	5	4	....	100	....	400	1,000
78	..do..	36	27	.90	......	32	2½	88	2	10	....	....	....	....	200	600
79	..do..	21	21	.91	19,200	20	20	88	2	7	3	100	....	....	275	650
102	Job	...	22	.87	19,450	2-5	35	85	5	5	5	....	....	....	300	....
121	Mfg.	....	....	......	......	30	50	......	....	....	....	....	....	....	125	325
144	..do..	31	19	......	......	......	4	R. B.	....	....	....	40	60	....	150	270
179	......	33	24	......	......	16	......	75	1	9	15	....	100	....	....	837
187	Mfg.	...	....	.86	19,300	12	40	80	....	10	10	70	30	....	275	....

29. ROUND, TILTING, OIL FURNACES, WITH LOW-

98	Mfg.	....	....	†0.93	19,500	16	25	80	16	2½	½	40	60	....	125	300
189	Ref.	....	....	......	......	......	......	Y. B.	...	....	....	....	100	....	....	400
189	..do..	....	....	......	......	......	......	......	....	....	....	....	....	....	....	800

30. ROUND, TILTING, OIL FURNACES, WITH

19	Mfg.	....	....	0.87	19,000	8	15	87	7	3½	2½	25	50	25	150	400
27	..do..	28	28	.86	......	3	20	Bz.	....	....	....	100	....	....	125	200
37	..do..	....	....	......	......	3½	6	(†)	....	....	....	....	Mostly.	....	125	375
43	......	....	....	......	......	3	......	R. B.	....	....	....	....	100	....	125	300
69	Mfg	....	24	......	......	25-30	3	R. B.	....	....	....	....	....	....	125	300
82	..do..	31	24	([c])	......	†140	15	80	4	8	4	60	40	....	300	625
85	..do..	....	....	.91	......	80	60	R. B.	....	....	....	100	....	....	125	300
152	..do..	29	18½	.87	19,000-19,300	12-20	3½	90	1	8	1	45	35	20	275	750
176	Job.	....	....	([f])	([f])	7-10	......	R. B.	....	....	....	....	Some.	Some	125	300
190	......	....	....	......	......	†10	80	85	5	5	5	....	....	....	125, 150, 275	....

[a] Average.
[b] Special crucible.
[c] Patched every 15 heats.
[d] Patched every 25 heats.
[e] Less than 0.94.

of furnaces and with various fuels—Continued

† indicates that notes on the reply number affect significance of figures so designated.]

FURNACES MELTING LOW-ZINC ALLOYS.

Speed of melting.											Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Cu.ft. gas.*	*Pct.*	*Pct.*		
6	9	1.5	4	1,800	200	0.5	800	20	......	......	6-4	....	73	Average.
8	9	1.1	......	2,240	220	.45	......	38	......	......	......	1.5	74	Special.
......	9	......	......	......	......	......	......	......	......	......	5	....	83	Average.
2	12	6(?)	2	900	75	1.3	......	......	......	......	......	....	......	Do.
2-5	10	5-2	......	*a* 687	69	1.5	215	18	......	480	7.3	5.8	103	Do.
6	9	1.5	4	1,080	120	.8	480	21	450	440	5	3	107	Do.

PRESSURE AIR, MELTING LOW-ZINC ALLOYS.

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
										Gals. oil.				
4	10	2.5	6	1,000	100	1	600	29	(†)	3	4	3-2.5	74	Average.
7	11	1.7	5	1,680	153	0.7	765	21½	525	(†)	1.5	....	74	Do.
†3	10	3.3	2	1,500	150	.7	300	20	350	2.5	3.5	2.75	79	Do.
5	10	2	......	2,500	250	.4	......	19	550	2.6	......	....	80	Do.
6	11½	1.9	......	1,500	130	.8	......	33	1,500	*2.5	......	3.5-3.0	83	Do.
5	10	2	2	5,000	500	.2	1,000	12	900	2.5	2.5	....	84	Do.
2	7	3.5	2	1,200	170	.6	340	3-10	......	3.3	*9-8	....	86	Do.
5	8	1.6	2	3,250	405	.25	810	22	......	1.9	0.42	....	87	Special.
4	9	2.2	4	......	......	......	......	......	......	......	......	....	98	Average.
3	10	3.3	2	975	98	1	198	10-18	......	(†)	......	....	101	Do.
4	8	2	3	1,080	135	.8	405	18	......	3	6.5	....	103	Do.
4	10	2.5	......	3,350	335	.3	......	......	1,200	1.2	1.5	1	108	Do.
7½	.....	2	......	......	......	......	......	13	......	......	1.6	....	110	Do.

PRESSURE AIR, MELTING HIGH-ZINC ALLOYS.

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
6	8	1.3	3	1,800	225	0.45	675	25	650	3-2.5	3	*0.5(?)	97	Average.
3	10	3.3	3	1,200	120	.8	360	27	300	......	5.5	....	112	Do.
2	10	5	2	1,600	160	.55	320	32	200	......	......	....	112	Do.

HIGH-PRESSURE AIR, MELTING LOW-ZINC ALLOYS.

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
5	9	1.8	2	2,000	222	0.45	444	27	1,000	3	†5.4	4.4	77	Average.
2	8	4	......	400	50	2	......	16	(*c*)	......	4.1	....	79	Do.
5	9½	1.9	2	1,875	195	.5	390	25	(*d*)	†5	*5	....	80	Do.
2	8	4	2	600	75	1.3	150	32-35	......	3.7	3	....	81	Do.
7	10	1.4	2	2,100	210	.45	420	27	700	2.2	......	....	85	Do.
2	5	2.5	......	......	250	.4	......	......	......	......	......	....	92	Do.
3	8	2.7	......	900	110	.9	......	10-18	......	......	2.5	....	93	Do.
†3	9	3	4	2,250	250	.4	1,000	12	......	1.8	†0.51	(†)	104	Do.
5	9	1.8	3	1,500	166	.6	500	15-30	300	*2	5	3	108	Do.
8	10	1.3	4	......	......	......	......	35	1,200	(*g*)	*5	....	112	Do.

f California crude oil. *g* Estimated at 6 gallons (?). See notes on Reply 190.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions;

31. ROUND, TILTING, OIL FURNACES, WITH HIGH-

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply. Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5a	5b	5c	5d	6				7			8	9
		In.	In.		Per lb.	Oz.	Lbs.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Lbs.
30	Mfg.	....	...	.....	......	10	75	75	15	5	5	....	....	....	60	160
61	..do..	....	...	0.90	(a)	(b)	(b)	67	26	....	7	35	45	20	125	300
83	..do..	36	36	.91	19,700	20	90	(†)	(†)	(†)	....	50	45	5	....	500
86	..do..	....	....	.88	......	......	17-20	Mn. Bz.	....	....	....	....	....	....	600	1,800
100	..do..	....	....	.....	......	16	15	Y. B.	....	....	....	....	....	....	125	350
117	..do..	....	....	.84	......	2½	3-4	58	39	....	3	50	50	....	(c)	733

32. OPEN-FLAME, TILTING, OIL FUR

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
15	Mfg.	Spherical.		.90	19,000	20	15	79	9	3	9	20	40	40	......	650
16	Ref.	...do..		......	......	......	......	R. B.	....	....	....	....	....	100	......	......
19	Mfg.	...do...		.87	19,000	16	15	87	7	3½	2½	25	55	20	......	800
26	..do..	Egg...		......	......	13	15	R. B.	....	....	....	35	50	15	......	500
31	..do..	Cylindrical		.87	19,300	14	25	87	....	....	....	....	....	....	......	1,125
39	..do..	Spherical.		.83	......	8-16	(c)	85	6	5	4	5	85	10	......	750
42	......	...do...		.87	......	12	......	R. B.	....	....	....	....	....	....	g 750	......
47	Mfg.	...do..		......	......	......	......	85	5	5	5	50	50	......	......	500
54	..do..	...do...		......	......	18	......	80	7	6	7	15	55	30	......	500
63	..do..	Egg....		......	......	12	20	88	3	5	4	5	55	40	g2,000 g1,000	1,750 917
65	..do..	Spherical.		.91	19,500	14	30	80	....	10	10	....	60	40	......	750
67	..do..	...do...		.90	......	......	10	80	....	10	10	....	(h)	(h)	......	600
67	..do..	...do...		.90	......	......	10	80	....	10	10	....	....	....	......	1,540
73	..do..	Egg....		.86	19,400	16	40	85	1	11	3	....	....	....	(†)	812
78	..do..	Spherical.		.90	......	......	......	......	....	....	....	....	....	....	......	710
80	..do..	Egg....		.87	(f)	12	30	R. B.	....	....	....	....	100	....	......	500
80	..do..	Spherical.		.87	(f)	12	30	R. B.	....	....	....	....	100	....	......	700
81	..do..	...do...		......	......	14	35	88	2	10	....	10	70	20	......	1,000
84	..do..	...do...		.96	(†)	12-15	......	88	2	10	....	....	....	....	......	......
91	..do..	Cylindrical.		......	......	18	10	85	5	5	5	45	25	30	......	700
92	..do..	Spherical.		......	......	10	22	R. B.	....	....	....	....	....	....	g 750	250
96	..do..	Egg....		.87	......	11	5½	Pb. Bz.	....	....	....	75	15	10	(†)	2,500
156	..do..	Spherical.		.87	19,000	8	20	88	2	10	....	....	....	....	......	2,500
169	..do..	...do...		......	......	32	30	85	5	6	4	45	40	15	......	600
174	..do..	...do...		......	......	12	30	R. B.	....	....	....	50	35	15	......	815
175	..do..	...do...		......	......	15	35	R. B.	....	....	....	60	40	....	......	2,000
175	..do..	Egg....		......	......	15	35	R. B.	....	....	....	60	40	....	......	500
179	..do..	...do...		......	......	16	......	75	1	9	15	....	....	....	......	1,200
185	..do..	Rectangular.†		.95	18,000	9	20	80½	11½	7	1	5	70	25	......	1,625

a Over 18,000 B. t. u.
b Steam atomization.

c Special crucible.
d Patched every 90 heats.

of furnaces and with various fuels—Continued.

† indicates that notes on the reply number affect significance of figures so designated.]

PRESSURE AIR, MELTING HIGH-ZINC ALLOYS.

Speed of melting.											Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Gals. oil.*	*Pct.*	*Pct.*		
5	10	2	10	800	80	1.2	800	15–35	900	0.7–1.2?	*1.5–1	....	79	Average.
6	8	1.3	1½	1,800	225	0.45	340	43	900	1.8	†5.6	....	84	Do.
1	.....	(†)	6	500	....	....	....	8	......	5	4.7	†3	92	Do.
1	8	8?	6	1,800	225	0.45	1,350?	....	......	*2	......	....	93	Do.
6	9	1.5	3	2,100	230	0.45	690	45–50	d1,800	......	4	3.5	97	Do.
3	8½	2.8	2	2,200	250	0.4	500	20	225	2.5	3.6	2	101	Do.

NACES MELTING LOW-ZINC ALLOYS.

6	9	1.5	2	3,810	425	0.24	850	......	5,000	2.89	5.2	3.6	74	Average
......	......	......	......	......	......	......	......	......	......	......	17–6	....	75	Do.
5	9	1.8	1	4,000	444	0.22	444	......	500	3	†5.4	4.4	77	Do.
7	9	1.3	½	3,500	390	0.25	195	......	......	3.1	4	2.3	79	Do.
5	11½	2.3	2	5,625	490	0.20	980	......	250	3	3.3	....	80	Do.
4	6	1.5	2	....	500	0.20	1,000	......	300	2.9	4–2.5	3.5–2	80	Do.
4	.....	.....	1	f1,144	......	......	......	......	......	4.4?	4	3.5	81	Do.
9	9	1	2	4,500	500	0.20	1,000	......	1,350	2.2	2	....	81	Do.
10	11½	1.1	......	5,000	450	0.22	......	......	6,000	2.5	†4	†3	83	Do.
4	10	2.5	2	7,000	700	0.14	1,400	.....	600 800	2.86	3	2.7	84	Do.
6	10	1.7	2	5,500	550	0.18	1,100		1,200–1,500	2.48				
4	9	2.2	2	3,000	333	0.30	666	......	400–600	1.4	3	1.5	84	Do.
5	9	1.8	......	3,000	333	0.30	......	......	900	2.3	3	2.25	84	Do.
5	9	1.8	......	7,800	867	0.12	......	......	900	2	3	2.25	84	Do.
4	10	2.5	1	3,250	325	0.31	650	......	1,200	2.4	5.2	4.55	86	Do.
6	7½	1.3	......	550	....	0.18	......	......	....	†4.8	(†)	....	86	Do.
4	8	2	......	2,000	250	0.40	......	......	1,200	2	3	....	90	Do.
4	8	2	......	2,800	350	0.29	......	......	....	2	3	....	90	Do.
3	5	1.7	2	....	600	0.17	1,200	......	900	1.7	4	2.5	90	Do.
......	......	......	......	300–1,500	....	......	......	......	....	2	*5	*4 2	93	Do.
4	9	2.2	2½	2,800	311	0.34	780	......	1,000	3	......		96	Do.
15	10	0.7	1	3,700	370	0.27	370	......	400	2.7	......	....	96	Do.
6	13	2.1	2	15,000	1,150	0.09	2,300	......	900	1.53	4	3	97	Do.
2	2	1	......	....	2,500	0.04	......	......	600	4.5–3	......	*3	104	Do.
(†)	7½	1.2	1½	3,600	500	0.20	750	......	1,000	2	6	....	107	Do.
7	8	1.1	1	5,700	710	0.14	710	......	....	2	(†)	....	108	Do.
5	9	1.8	1½	10,000	1,111	0.09	1,666	......	....	2	(†)	....	108	Do.
6	9	1.5	......	3,000	333	0.30	......	......	....	2	2	....	108	Do.
8	10	1.2	......	10,060	1,006	0.10	......	......	400	2.9	5	....	108	Do.
2	10?	5?	2	3,250	325?	0.31	750	......	300	1.2	6.3	....	109	Do.

e Over 20 pounds
f Average.

g Rated capacity.
h "50 per cent scrap."

i Over 18,000 B. t. u.

Details of brass-melting practice in various types

[* Designates estimated results rather than results based on average running conditions.]

32. OPEN-FLAME, TILTING, OIL FURNACES

Reply No.	Nature of plant.	Height or shape of furnace	Diameter or inside length of furnace.	Fuel and air supply. Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5a	5b	5c	5d	6				7			8	9
		In.	*In.*		*Per lb.*	*Oz.*	*Lbs.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		*Lbs.*
187	Mfg.	Egg....		.86	19,300	12	40	Pb. Bz.	....	....	....	70	30	....	......	1,000
188	..do..	Spherical.		.86	19,000	8	90	R. B.	....	....	....	60	40	....	....	870
191	..do..	...do...		.85	19,500	8	20	87	6½	3½	3	30	40	30	......	1,600
196	..do..	...do...		......	......	......	......	......	10	....	....	......	75	25	......	700
204	..do..	Egg....		......	......	8-10	a5(?)	R. B.	....	....	....	....	100	....	....	1,0[illegible]

33. OPEN-FLAME, TILTING, OIL FUR

Reply No.	Nature of plant.	Height or shape of furnace	Diameter or inside length of furnace.	Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
2	Mfg.	Spherical.		.89	19,160	22	40	76	18	3	3	......	....	......	....	500
3	..do..	...do...		.89	19,160	22	40	Mn. Bz.	....	....	3	......	....	100	....	10,000
81	..do..	Egg....		......	......	14	35	62	37	....	1	10	80	10	....	1,000
83	..do..	Cylindrical.		.91	19,700	32	90	Y. B.	....	....	....	....	90	10	....	800
85	..do..	Egg....		.91	......	......	......	Mn. Bz.	....	....	....	....	....	....	....	800
86	..do..	...do...		.95	18,800	......	......	......	15-40	....	....	....	Mostly.	Some.	(†)	600
86	..do..	...do...		.95	18,800	......	......	......	15-40	....	....	....	..do ..	..do..	....	1,000
94	..do..	Spherical.		......	19,000	......	......	Y. B.	....	....	....	50	Some.	..do..	....	458
99	..do..	Egg....		......	......	11	......	79	13½	3½	3	......	....	....	....	250
104	..do..	Spherical.		.90	......	22	40	75	16	2	7	7	78	15	....	610
173	Roll.	...do...		......	......	16	30	60	40	....	....	80	20	....	....	2,500
189	Ref.	(†)		......	......	......	......	Y. B.	....	....	....	......	....	100	....	600
192	Roll.	Spherical.		......	......	......	......	65	35	....	....	......	....	....	....	....

34. OPEN-FLAME, NATURAL-GAS FUR

Reply No.	Nature of plant.	Height or shape of furnace	Diameter or inside length of furnace.	Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
					Per cu.ft.		*Oz.*									
15	Mfg.	Spherical.		......	1,059	20	4½	80	10	2	8	......	....	....	....	500
31	..do..	Cylindrical.		......	1,030	14	3	87	....	....	....	......	....	....	....	1,125

35. OPEN-FLAME, NATURAL-GAS FUR

Reply No.	Nature of plant.	Height or shape of furnace	Diameter or inside length of furnace.	Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Cu.	Zn.	Sn.	Pb.	New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
11	Mfg.	Spherical.		......	948	5	8	70	20	6	4	20	65	15	....	580
104	..do..	...do...		......	......	10	9	......	18	....	....	......	....	....	....	550

a Ounces.

of furnaces and with various fuels—Continued.

† indicates that notes on the reply number affect significance of figures so designated.]

MELTING LOW-ZINC ALLOYS—Continued.

Speed of melting.											Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Gross.	Net.	See notes on page	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Gals. oil.*	*Pct.*	*Pct.*		
7	7	1	2	7,000	1,000	0.10	2,000	....	875	1.4	....	......	110	Average.
2	2⅓	1.15	1	1,740	758	0.12	758	....	450	3.9	†3.5	......	111	Do.
4	7½	1.8	3	6,600	900	0.11	2,700	....	500	2	3.6	......	113	Special.
5	10	2	3	3,500	350	0.50	1,050	....	......	1.5	4.5	......	114	Average.
6	11	1.8	1	10,000	909	0.11	909	....	1,040	1-1.25	†3	......	116	Do.
NACES MELTING HIGH-ZINC ALLOYS.														
†10	10	1	2	5,000	500	0.20	1,000	....	(*b*)	2.14	1.4	1.2	70	Average.
......	.....	.....	......	....	....	......	......	....	......	8	7	......	70	Do.
3	5	1.7	2	....	600	0.17	1,200	....	900	......	6	4	90	Do.
3	3½	1.1	(?)6	....	725	0.13	4,350?	....	900	3	4.7	†3	92	Do.
3	8	2.7	......	2,400	300	0.33	......	....	......	......	10	......	93	Do.
3	8	2.7	3	1,800	225	0.45	675	....	1,350	*2	5	2.5	93	Do.
3	8	2.7	1	3,000	375	0.27	375	....	......	*2	5	2.5	93	Do.
9	9	1	2	4,100	458	0.22	915	....	1,350	3	....	4.7	96	Do.
6	10	1.7	3	1,500	148	0.68	444	....	650	2.8	*5	*4	97	Do.
†7	10	1.4	......	4,250	425	0.23	......	....	4,000	3.2	3.6	2.2	98	Do.
5	9	1.8	......	12,500	1,390	0.07	......	....	750	......	2	......	108	Do.
5	10	2	1½	3,000	300	0.33	450	....	......	......	10-12	......	112	Do.
......	.....	.....	......	....	....	......	......	....	......	......	3.4	......	113	Do.
NACES MELTING LOW-ZINC ALLOYS.														
										Cu. ft. gas.				
......	.....	0.7	......	....	....	0.14	......	....	......	341	5	3.5	74	Average.
......	.....	.....	......	....	....	......	......	....	......	320	3.3	......	80	Do.
NACES MELTING HIGH-ZINC ALLOYS.														
3	10	3.3	1	1,692	170	0.59	170	....	750	280	6.2	5.5	74	Special.
......	.....	1.3	......	....	425	0.23	......	....	......	200-255	2.5-2.2	......	98	Do.

b Lining not replaced in 24,000 heats, but repaired when necessary.

Details of brass-melting practice in various types

[*Designates estimated results rather than results based on average running conditions;

Reply No.	Nature of plant.	Height or shape of furnace.	Diameter or inside length of furnace.	Fuel and air supply. Specific gravity of oil.	B. t. u. per pound or per cubic foot.	Air pressure at burner.	Pressure of fuel at burner.	Analysis of charge. Cu.	Zn.	Sn.	Pb.	Composition of charge. New metal.	Heavy alloy.	Light alloy.	Crucible maker's No.	Weight of charge.
1	2	3	4	5a	5b	5c	5d	6				7			8	9
36. REVERBERATORY, OIL FUR																
		In.	In.		Per lb.	Lbs.	Lbs.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Lbs.
79	Mfg.	(†)		0.91	19,250	27	20	88	5	6	1	None.	......	......	......	2,000-4,000
80	..do..	(†)		.87	19,000	1	20	R. B.	....	....	....	......	......	......	20,000	10,000
82	......	(†)		.95	......	15	†140	R. B.	....	....	....	......	([d])	......	......	4,000
37. REVERBERATORY, OIL FUR-																
						Lbs.	Lbs.									
81	......	(†)		......	......	1½	35	70	27	3	....	......	80	20	......	14,000
83	......	(†)		0.91	19,700	90	90	Mn. Bz.	....	....	....	......	85	15	......	9,000
173	Roll.	(†)		......	......	1	55	60	40	....	....	80	20	......	......	4,000
38. REVERBERATORY, SOFT-COAL FUR																
180	Mfg.	(†)		([f])	......	......	......	88	2	10	....	......	......	None.	......	10,000
202	..do..	(†)		([g])	......	......	......	81	8	6	5	......	75	25	......	2,135
39. REVERBERATORY, SOFT-COAL FUR																
173	Roll.	(†)		([h])	......	......	......	60	40	....	....	80	20	......	......	7,000
180	Mfg.	(†)		([i])	......	......	......	Mn. Bz.	....	....	....	......	100	......	......	10,000
180	..do..	(†)		([i])	......	......	......	Mn. Bz.	....	....	....	100	......	......	......	10,000

[a] Over one-fourth; see notes on Reply 79.
[b] 2 burners used.
[c] 3 burners used.
[d] All scrap.

of furnaces and with various fuels—Continued.

† indicates that notes on the reply number affect significance of figures so designated.]

NACES MELTING LOW-ZINC ALLOYS.

Speed of melting.											Melting loss.		Remarks.	
Heats per day.	Hours per day.	Hours per heat.	Furnaces per tender.	Metal per furnace per day.	Metal per furnace per hour.	Time per cwt. of metal.	Metal per tender per hour.	Life of crucible.	Life of lining.	Fuel consumption per cwt. of metal melted.	Gross.	Net.	See notes on page —	Conditions of test, average or special.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Lbs.	*Lbs.*	*Hrs.*	*Lbs.*	*Heats.*	*Hts.*	*Gals. oil.*	*Pct.*	*Pct.*		
2	7	3.5	(*a*)	5,565	800	0.12	200	....	200	1.11	5	......	87	(*b*)
2	8	4	......	20,000	2,500	0.04	......	....	......	2.5-3	5	......	90	(*c*)
1	2½	2.5	⅓	....	1,600	0.06	530	....	600	1.25	3.5	......	92	Average.
NACES MELTING HIGH-ZINC ALLOYS.														
1	3	3	½	....	4,666	0.02	2,333	....	......	1.2	5	3	90	(*c*)
1	6	6	1	9,000	1,500	0.07	1,500	....	......	1.28	3.6	......	92	Average.
4	9	2.2	......	16,000	1,777	0.06	......	....	1,100	......	2	......	108	(*e*)
NACES MELTING LOW-ZINC ALLOYS.														
										Lbs. coal.				
......	......	......	......	....	....	......	......	....	......	......	2	1	108	Average.
2	10	5	1	4,270	427	0.23	427	....	1,200	88	....	2.5	115	Do.
NACES MELTING HIGH-ZINC ALLOYS.														
2	8	4	(†)	14,000	1,750	0.06	†520	....	500	50½	5	......	108	Average.
1	4	4	½	....	2,500	0.04	1,250	(†)	(†)	18	4-3	......	108	Do.
1	5	5	½	....	2,000	0.05	1,000	(†)	(†)	......	....	......	108	Do.

e 1 burner used.
f Air jet under grate.
g Mechanical stoker; top and bottom blast.
h Natural draft.

NOTES.

Reply 1, subdivision 18.—Figures based on one day's run. Low-pressure air considered best.

Reply 2, subdivisions 1 and 33.—A crucible lasts 18 heats on copper in the coke furnaces.

The open-flame oil furnace has been run so as to give 26 heats of 500 pounds, or 13,000 pounds of metal in 10½ hours, the metal being taken away as fast as it is ready and recharging being done without delay.

Fuel-oil tests: Flash test, 105° C.; fire test, 116° C.; cold test, 4° C.; viscosity test, 136 sec. at 40° C. (in Saybolt viscosimeter).

The open-flame furnaces have not been relined in eight years, but are patched at the end of the week. The charging hole and pouring spout are patched each morning. The pouring spout has been reduced in size, the effort being to maintain a pressure considerably above atmospheric, with the idea that this may retard the volatilization of zinc. The open-flame furnace is capable of melting a large tonnage with a lower loss and less cost than the crucible or any other form of furnace.

[The fuel and loss figures are based on complete and careful shop records and are probably reliable.]

SPECIAL TEST.

A special test was made to compare a natural-draft, pit, coke-fired, crucible furnace with a tilting, open-flame, oil-fired furnace as to melting loss. Several different alloys were used, the charge in both furnaces for each alloy being the same as to analysis and composition.

Comparative results with coke furnace and with oil furnace.

Alloy No.	Analysis.	Coke furnace. Time of heat.	Coke furnace. Metal charged.	Coke furnace. Metal lost.	Oil furnace. Time of heat.	Oil furnace. Metal charged.	Oil furnace. Metal lost.	Average metal loss.
		H. m.	*Pounds.*	*Per cent.*	*H. m.*	*Pounds.*	*Per cent.*	*Per cent.*
1	....				1 45	1,003	0.4	0.7
					1 20	1,000	1.0	
		2 30	212	0.2	1 25	1,000	0.8	
2	....	3 45	207	7.0	2 5	842	4.1	5.2
					1 30	840	6.3	
3	....	3 30	208	15.0	1 35	840	7.3	7.3
4	....	2 30	250	3.2	55	500	1.2	1.6
					1 15	500	2.3	
					1 45	538	1.4	
5	87 Cu, 5 Zn, 5 Sn, 3 Pb.	4 00	274	0.9	1 35	600	1.0	1.6
					1 0	606	1.8	
					1 10	587	1.8	
6	Red brass	3 30	250	3.3	2 0	1,459	2.8	3.3
					2 0	1,460	3.8	
					1 50	1,220	3.5	
7	....	2 30	250	1.6	1 0	722	0.6	1.0
					1 5	800	1.1	
					45	598	1.3	
8	....	45	249	0.6	1 20	708	3.1	2.8
					1 0	810	2.3	
					1 10	803	3.2	
9	....	3 30	262	1.2	1 35	800	1.9	1.7
					1 5	777	1.7	
					1 30	762	1.5	

Total average loss in coke furnace, 3.42 per cent; in oil furnace, 2.48 per cent.
Average output of metal from coke furnace, 81.6 pounds per hour; from oil furnace, 591 pounds per hour.

Reply 3, subdivison 16.—When starting the operation of this pit type of oil furnace with low air pressure, the oil consumption ran about 2.7 gallons per hundredweight. Recently this figure has been reduced to about 1.7 gallons, the average being 2.2 gallons.

We have used at different times various types of both pit and tilting furnaces, fired with coke, coal, and oil fuel, and although the data on some of these furnaces are not available at the present time, the oil-fired furnace which is now in operation at our works we consider the best and most efficient that has come under our observation in an experience of over 30 years.

Our metal losses are very small, the metal melted is first-class, the life of the crucible is greater than that of the coal or coke fired furnace, the melting time of the heat can be controlled, and after the first heat, when the furnace has warmed up, the heats following can be taken off in from 42 to 65 minutes, using Nos. 70 and 80 crucibles and a metal mixture containing from 89 to 86 per cent of copper.

Have used various types of furnaces and the old-fashioned coal or coke pit furnace gives very good results if the factor of time in melting is of no value and the metal is not allowed to "soak."

Of the oil furnaces that have come under our observation and have been used by us there are three types exclusive of the furnace being used at the present time.

In the first (of the tilting type, of two makes) the metal was placed in a reservoir with the flame coming in direct contact with the metal.

In the second style, which was also of the tilting type, the metal was melted in a large crucible, and when melted was poured into a second, or carrying, crucible to the flasks.

The third was of the pit type without the combustion chamber. In this furnace the metal was poured into the flasks direct from the crucible in which it was melted.

All three of the foregoing types of furnaces depended on compressed air to atomize the oil, thereby making an oxidizing flame and, as a consequence, a large percentage of shrinkage and bad castings.

In the reservoir type of furnace, in which the flame came in direct contact with the metal, our experience was that really sound castings on which an internal test was required could not be produced, owing to the fact that the flame, coming in direct contact with the metal, burned out the alloys and made the metal hard; also to the fact that on being poured from the reservoir to the carrying crucible the metal became oxidized, volatilization set in, and a large proportion of bad castings resulted.

For castings of the nature of gear-wheel blanks, housings, bearings, etc., we have no doubt that this type of furnace may give satisfaction.

In the second type of furnace the pouring of the metal to the second, or carrying, crucible had the same effect on the metal as with the reservoir type.

The third, or pit type, without the combustion chamber referred to above, gave fair but not entirely satisfactory results. This furnace, as were the two types preceding, was equipped with compressed air, causing an excess of oxygen in addition to the tearing and wearing away of both linings and crucibles.

The roaring noise from several of this type of furnace in operation at the same time had a bad effect on the furnace men; it was a case of changing help continually.

Would also state that it has been our lot to use a coke-fired tilting furnace of two makes, and we are free to say that the foundry making castings containing a number of cored passages and requiring an internal test of, say, 200 pounds steam pressure, would make no mistake in giving this type of furnace a wide berth.

Our present installation of furnaces, equipped with the combustion chamber and burner of peculiar design, in which the oil is atomized mechanically by pressure from the oil pump, make our figures seem almost unbelievable. In a melt of 1,900,000 pounds for six months, bad castings from both shop and foundry were 2.4 per cent.

In this burner no compressed air is used; fan or blower air between 5 and 6 ounces is used—just enough for complete combustion, so that when the atomized oil is forced through the incandescent combustion chamber the oil becomes a gas and attains its greatest heat as it enters the furnace proper, which is about on a line with the bottom of the crucible.

[The pinch type of tongs is used, but three sets of tongs are kept, varying slightly in size, so that as the crucible becomes smaller through use a pair is always at hand that fits the crucible properly. No squeezing of the pots by the tongs is allowed.]

Reply 4, subdivision 11.—Net loss of metal and fuel consumption based on one day's run on No. 30 crucible.

Percentage of melting loss is the same in all sizes of crucibles. Loss on yellow brass is 2½ to 3 per cent.

Per pound of metal melted, a No. 50 crucible will take about 10 per cent less coal than a No. 30, and a No. 100 about 5 per cent less than a No. 30. The No. 100 does not increase in efficiency over the No. 30 as much as the No. 50 because of the thicker wall of fuel, which may be a little out of proportion.

Reply 5, subdivision 22.—At the beginning of 1913 we planned to replace this type of furnace by one burning coal, because of the high price and scarcity of oil, but have now (October, 1913) decided to keep the oil furnaces in operation for a while longer.

The oil consumption is from a test made several years ago and is not guaranteed to be correct.

The type of furnaces in the foundry was designed and built according to the ideas of the mechanical engineer and foundry foreman, both of whom are gone.

The purpose of using small crucibles is to produce the small castings we make in our foundry, such as small trimmings, lock parts, etc. At times there is so much of this class that with large crucibles we could not pour fast enough at the proper temperature. At the same time I realize that we can use, say No. 60 pots, to good advantage on our work in general, and the No. 35 on small work only, and we are using up a large stock that was on hand for some time before changing over to the larger size.

I do not like this furnace for several other reasons. In the first place it requires two men to roll back the cover, which is made of brick in an iron frame, and, secondly, as we use a lot of sheet-brass scrap, borings, etc., it requires opening a number of times during a heat, and while this is being done, which takes about 8 minutes each time, the blast must be shut off, and the furnace, being wide open, rapidly cools and retards the heat. This constant cooling is also very detrimental to the life of crucibles.

Reply 6, subdivision 15.—Through the hole in the cover a feeder is placed, which is nothing more than the crucible that has performed its service in the jacket, and has been removed after melting 30 heats. A hole is put in the bottom of this crucible, and the charge is placed in it, the flames going up through the metal contained therein. The actual melting is really done in the feeder or hood as we call it. The metal after having been melted in this way drops into the lower crucible, and is superheated.

The crucible is worn out at 30 heats, and is used for the hood or feeder. Crucibles will average over 40 if run until worn out, and if the furnace is operated continuously they average 50. We have had individual crucibles run as high as 105.

Gross melting losses are as follows: Yellow brass, 18.68 per cent; manganese bronze, 3.38 per cent; leaded bearing bronzes, 4 to 5.50 per cent.

The yellow brass here referred to is made largely from turnings and light brass. Manganese bronze is made from new metals. In remelting ingots this running loss would probably be less. The leaded bearing bronzes are made largely from scrap, turnings, etc. We have open-flame furnaces at another plant, also have the old-style pit furnaces at both plants. We consider the forced-draft, tilting, coke furnace the most economical furnace, as regards operation, of any at present on the market, but it does not give good results for light work. The open-flame furnaces do not compare in economy with these. We do not consider this type of furnace very satisfactory for small castings. The old type of the pit furnace we consider gives the best results as regards quality—that is, gives the best physical tests, pressure tests, and the best behavior in the foundry. This superiority is accounted for briefly as follows: (1)

Because the metal is cast direct from the crucible it need not be overheated to cast small work. (2) It is out of direct contact with fuel.

We operated for quite a number of years a forced-draft, tilting, coke furnace that had a square jacket. We afterwards remodeled the furnace and designed a round jacket, with a consequent saving of 17 to 20 per cent in fuel.

We do not know of any users of the forced-draft, tilting furnace who are using hard coal instead of coke.

In our first experience with this furnace we used 72-hour coke mixed with anthracite coal. This practice we abandoned years ago, and are now using 48-hour coke exclusively, which works far better and is cheaper. The 48-hour coke gives a better flame and quicker combustion.

Reply 7, subdivisions 1, 27.—Coke furnaces turn out a better grade of metal, with less shrinkage. On the gas furnace the loss on red metal is 4 to 6 per cent; on brass running 15 per cent or over in zinc the loss is 8 to 12 per cent. Coke furnaces are used almost entirely.

Data on a special test using natural gas are given below. A pit furnace was rigged for gas and a test run on an alloy of 83 per cent copper, 7 per cent zinc, 4 per cent tin, and 6 per cent lead, the metal being poured into ingots. The test was run on parts of four different days.

Results of special test with pit furnace using natural gas.

Day.	Length of heat.		Gas used.	Material charged.	Charged.	Recovered.	Gross melting loss.	Gas used per hundredweight.
	H.	*m.*	*Cubic feet.*		*Pounds.*	*Pounds.*	*Per cent.*	*Cubic feet.*
1	1	8	430	Scrap	184	172.5	6.7	234
1	1	5	433	Ingot	170	167.5	1.5	254
1		50	353	...do	174	...	...	203
1		55	429	...do	163	...	...	263
1		50	398	...do	152	...	...	264
2[a]	1	18	607	Scrap	191.5	187	2.3	318
2	1	7	469	Ingot	189	187	1.05	248
2		53	366	...do	175	170	2.9	209
3[a]	1	38	713	Scrap	152.5	143	6.2	470
3		52	357	Ingot	169.5	166	2.1	211
3		55	409	...do	168	...	...	242
4	1	1	477	...do	157	...	...	304
4	1		453	...do	180	...	...	252
4		58	444	...do	173.5	...	...	255
4		57	414	...do	175.5	...	...	236

[a] First heat with cold furnace.

Average gross melting loss on scrap, 5.1 per cent; on ingot, 1.9 per cent. Average gas consumption, 264 cubic feet per hundredweight.

Reply 8, subdivisions 1, 19.—A comparative test of the gross loss in melting red brass in 225-pound heats, three-fourths new metal, one-fourth gates, gave results as follows:

Melting loss on red brass in two types of furnaces.

Kind of furnace.	Time of melt.	Metal loss.
	Hours.	*Per cent.*
Oil	$2\frac{1}{4}$	1.54
Do	$2\frac{3}{4}$	1.65
Coke	$3\frac{1}{2}$	2.00
Do	4	2.48

Plotting loss against time gives an almost straight-line relation between length of heat and percentage lost. The heats were slower than our regular practice.

The tests were made by weighing the cold metals, weighing the hot crucibles and metal and then weighing the empty hot crucibles after the metal had been poured.

The crucible life is much better in the coke furnace than in the oil. With oil at a reasonable figure, the coke furnaces are on the whole the more expensive to operate.

Reply 9, subdivision 1.—[The gross loss of 4.2 per cent includes all losses on castings up to the time they are sold, and would be less on the basis of metal actually melted because the gates are remelted and because some of the loss occurs in grinding.] "Grab" tongs used. Crucibles last much longer than when pinched with ordinary tongs.

Reply 10, subdivision 28.—Oil burner takes oil at 30-pounds pressure, and a little air for vaporization at 30-pounds pressure. Volume of air for combustion supplied through a concentric tube at 8 to 12 ounces. These furnaces are very quiet. One can converse in ordinary tones while standing in the midst of a battery of them. They can be easily controlled so as to give a reducing flame. The oil and air are preheated by the flue gases. The furnaces have not been relined since they were built, the only repairs being occasional face patching with carborundum fire sand when replacing crucibles.

Although we do not use the open-flame furnace, just as good metal can be made with these, and even sound copper castings produced.

Reply 11, subdivisions 5, 35.—Open-flame furnace is patched every day. It gives about 25 per cent loss on borings. The figures given are from a 22-day test. The coke furnaces are not used to any extent, most of the tonnage being from the open-flame gas furnaces.

Reply 12, subdivisions 11, 35.—One tender handles 3 gas and 7 coal furnaces. The loss on manganese bronze in gas furnaces is 6 per cent. Coal furnaces are relined three times in 14 months; covers and cast-iron flues every 6 months; gas furnaces once in 12 months; covers and stool bricks renewed every 6 months.

Crucible life is 18 to 23 heats in coal furnaces; 20 to 25 in gas, and then 3 to 5 more in coal furnaces. On account of difficulty of cleaning metal from bottom of gas furnaces, we take no chances on a crucible cracking in them. There is practically no difference in the life of a No. 60 and a No. 80 crucible.

The gas furnaces supply a little cleaner metal with a slightly lower oxidation than the coal furnaces, but there is very little difference.

Reply 13, subdivision 28.—Oil consumption can not be given, as the furnaces are not metered, oil being used for other purposes beside melting. We also have pit fires [coke or coal, on which no data were given], the advantages of the oil furnace being a reduction in the cost of fuel and labor and better working conditions for the men.

Reply 14, subdivisions 1, 16.—The oil furnace is very good when operated by an intelligent man who is anxious to keep things clean and running smoothly. Otherwise, the bottom of the furnace gets clogged with slag and metal and hence the oil does not get proper access. Carbon and a smoky fire result, which slows up the furnace and makes a poor showing. Oil burner using oil under high pressure and air under low pressure is the best we ever tried, and we can get better results than with coke when the burner is operated properly in a clean furnace. For the average Polish furnace tender, the common, natural-draft, coke furnace with proper coke space produces the least all-around good results. For melting yellow brass, the coke furnace gives better results than the oil, owing to a somewhat slower fire and also owing to the fact that the men in puddling the brass are able to work over the coke fires better than over the hot oil fires. The metal must be poked down very frequently to prevent excessive zinc loss in refining borings.

Reply 15, subdivisions 24, 27, 32, 34.—In our opinion both of the types of furnaces that we use have their advantages. The losses in the open-flame furnace are higher, but the fuel consumption and attendance is very low and the cost of crucibles is eliminated entirely. The slag from these furnaces comes out in rather large matted

pieces, but these we now successfully crush and recover the metal from them. We believe this type of furnace needs closer watching, but when operated with competent supervision we get very good results from the metal melted in it. The air on the gas furnaces is preheated by passing around the furnace, through a hollow casing, before going to the burner. Gas is seldom used on the open-flame furnaces.

To show the effect of the speed of the heat on the loss of metal in melting, the following results of tests are submitted. Eight heats in the No. 125 gas furnace, starting in the morning or at noon after the furnace had cooled somewhat, averaged 1 hour 40 minutes, with an average shrinkage of 1.97 per cent. Twelve heats after the first averaged 1 hour 9 minutes, and gave an average shrinkage of 1.12 per cent. The alloy was 87½ per cent copper, 5½ per cent zinc, 5½ per cent tin, 1½ per cent lead, and the charge consisted of 300 pounds of clean gates.

Records on 18 No. 50 crucibles in the pit gas furnace show an average life of 61 heats, and on 86 No. 60 crucibles an average of 55 heats. These pots were pulled with the "grab" type of tongs. Eighteen No. 125 crucibles in the tilting gas furnace averaged 43 heats, and 11 No. 275 crucibles in the same type of furnace averaged 12½ heats. Taking the crucible cost per pound of metal melted in the No. 50 as 100 per cent, the crucible cost in the other sizes was: No. 60, 123 per cent; No. 125, 173 per cent; No. 275, 705 per cent.

Reply 16, subdivision 1.—Our work is very light, 0.10 inch being the standard thickness, which makes it necessary for us to have a very hot metal and also for each molder to have a furnace from which to get his metal; therefore the oil furnace for our work was not very satisfactory.

We have had a great amount of experience with oil furnaces; have tried out five different makes of same. We installed four different makes of the pit type, put them alongside of one another, and equipped each with a blower and a separate oil tank so as to get the exact amount of oil used and the pressure that was called for by the maker of the furnace. After the furnaces were installed we had a representative of each furnace company come to our plant and start his furnace; we were able to give the exact oil and air pressure required, and arranged the furnace to work just as the agent requested.

After each furnace had been demonstrated and we thoroughly understood how they should be operated, we had each one overhauled, relined, and made as good as new. We then started the four on a three months' test, comparing them with four coke furnaces working as nearly as possible under the same conditions in regard to the amount of metal required; we found that the coke furnace for our work was the best and cheapest. We had more trouble with our metal from the oil furnaces; our loss from spongy work was much greater. I believe this was greatly due to the fact that we could not keep our metal covered with charcoal, which caused more or less oxidation. Another condition which we discovered was that the greatest heat in the oil furnace was at the top of the crucible, which we have found is not in favor of a good metal and causes a great amount of oxidation.

Although the actual cost of melting with oil was much cheaper, taking into account the loss in melt and the quality required for our work, coke melting is the cheapest in the end.

We found it much more difficult for the melter to work oil furnaces than coke furnaces. One of our oldest melters had the "brass shakes" when operating these furnaces, something we have never had with coke. Although we could get more heat from an oil furnace, we could not use the metal, and a great amount of oil was used in heating the furnace, which increased the cost of melting metal.

SPECIAL TEST.

A special test was made to compare four different oil-fired pit furnaces with a natural-draft, pit, coke-fired furnace.

Red brass was the alloy melted and the crucible used was No. 40. The results follow:

Results of melting red brass in four oil furnaces and one coke furnace.

Item.	Oil No. 1.	Oil No. 2.	Oil No. 3.	Oil No. 4.	Coke.
Metal melted in test.........pounds..	20,930	17,067	18,998	21,727	19,430
Melting time.........hours..	121.5	114.75	123.75	119.25	12[illegible].75
Time per 100 pounds melted.........do....	0.59	0.67	0.65	0.55	0.64
Fuel per 100 pounds melted.........gallons..	5.86	5.08	6.0	5.05	a 55
Gross melting loss.........per cent..	0.88	0.63	0.65	0.74	0.[illegible]

a Pounds.

The average net melting loss in the other coke furnaces in the foundry during this test was 0.51 per cent. The linings were burnt out at the end of the test, whereas that of the coke furnace was in good condition. All of the furnaces were worked under the same conditions as with the regular coke furnaces. One or two more heats per day might have been taken from the oil furnaces, but only the amount needed in regular practice was taken out. There was thought to be a larger proportion of bad castings from the oil furnaces than from the coke.

[This test is of interest in several ways. It shows that the loss on red brass can, by exercising care, be kept well under 1 per cent, either in coke or oil furnaces. It was considered to prove that the oil furnaces were inferior for the conditions in that foundry. It hardly seems, however, to have taken into consideration sufficiently the possible utilization of the speed of oil fuel. This foundry deals with very light castings and requires extra hot metal. A separate furnace is run for each molder and the metal is held in the furnace until he is ready for it, even though the metal has been ready to pour previously. The coke furnaces in the test were run faster than the normal rate, as shown by the figures for reply 16 in subdivision 1 of the table. The other replies in subdivision 1 lead to the belief that with a No. 60 crucible, even on work requiring such hot metal 40 pounds of coke per 100 pounds of metal should be sufficient. The smaller crucible (No. 40) will give a lower fuel efficiency, and as hotter metal is required, the figure of 55 pounds per 100 shows a fair fuel efficiency for coke furnaces. The oil consumption shown in the tests, averaging 5.5 gallons, is high. The results presented in subdivisions 16 and 18 show that for a No. 60 crucible the normal figures run from 1.7 to 3.3 gallons. Allowing an increase in the ratio of 40 to 55 over this figure of 3.3 gallons oil consumption, on account of the use of a smaller crucible and the need for hotter metal, the oil furnaces should not have taken over 4.5 gallons per hundredweight at the outside, if run at full capacity.]

Reply 17, subdivision 10.—[In tabulating the pounds of metal per furnace tender per hour for rolling mills, it was impossible to keep the same basis of comparison as in foundries melting metal for sand casting. In such a foundry, the furnace tender seldom has anything to do with the metal after it has been taken from the fire; that is, after the pot has been pulled from a pit furnace or the metal poured into the ladle from other types. The metal goes into the hands either of the molder and his helper, who carry it to the molds by hand or by crane and pour off, or, in an increasing number of plants, of a "pouring gang," the members of which are trained in pouring and whose sole duty is to take the metal from the furnace tender, pour it, and return the crucible or ladle to the melting floor, thus allowing the molder to keep uninterruptedly at his work. The use of a pouring gang has met with some objection in shops operating under the piecework system, as it has been thought that the molder was thus held responsible for scrap caused by faulty pouring. The success reported by so many shops in the use of a pouring gang indicates that the objection is not serious, as scrap from faulty pouring is as a rule easily recognizable as such, and as the pouring gang soon become

expert at pouring, it being easier to train a picked gang to pour than to train each individual molder, the scrap is less in the long run.

In rolling mills the furnace tender, called the caster, has two, and sometimes three, helpers, and this gang handles in general from 8 to 10 fires, and makes four to five "rounds" at a shift of about nine hours. Most rolling mills run double shifts, the fires being poked out at the end of each shift, on account of the accumulation of ash, the next shift building the fires anew. The caster and his helpers melt the metal, which is usually brought to them in trays, each tray with the proper charge of new metals and scrap for a single crucible, pour it into the iron molds, pull out the ingots or billets, and dress the molds with oil. Hence in the tabulation of production in rolling-mill practice, "metal per furnace tender per hour" refers both to metal melted and metal poured into ingots, and not solely to metal melted, as in foundries in which sand castings are made. Most of the refining plants listed probably have the furnace tender both melt and pour metal into ingot molds, though the data on this detail are in most cases not clear.]

Reply 18, subdivision 1.—We have a draft sufficient to get out three heats of red metal in 10 hours, but we get out only two heats per day. We run the furnaces from 7.30 to 11.15 and from 12.30 to 4.15. It takes $2\frac{1}{4}$ bushels of coke to melt 100 pounds of metal. The proportion of different alloys melted is 70 per cent red bronze, 5 per cent yellow brass, 10 per cent manganese bronze, 10 per cent copper, 5 per cent miscellaneous.

[Assuming 1 bushel of coke to weigh 40 pounds,[a] this would be equal to 90 pounds of coke per hundredweight of metal melted, the high fuel consumption being probably due to the fact that the furnaces are not run to full capacity.]

Reply 19, subdivisions 30, 32.—The figures tabulated for gross and net metal losses are from very complete yearly records and cover running conditions. The results with two tilting oil furnaces with crucibles and with two open-flame oil furnaces are grouped together, as records are not available for each type separately.

In two tests on the open-flame furnace, a 575-pound charge 85 per cent heavy alloyed material and 15 per cent borings was used. Analysis of the charge showed 87 per cent copper, 7 per cent zinc, $3\frac{1}{2}$ per cent tin, and $2\frac{1}{2}$ per cent lead. The gross loss in melting was 2.43 per cent.

With an 800-pound charge of the same alloy, consisting of 80 per cent of heavy alloyed material and 20 per cent of borings, the gross loss was 2.25 per cent.

The average loss in tests throughout the year was 2.25 per cent. We have not been able to get any better results out of trials of the crucible oil furnace than from those with the open-flame furnace. In spite of the fact that many are against using a furnace in which the flame is played directly upon the material charged, we feel that these figures are a good thing to present and let other arguments rest.

Reply 20, subdivision 18.—We have five pit oil furnaces taking No. 70 crucibles, three pit oil furnaces taking No. 200 crucibles, two tilting oil furnaces taking No. 275 crucibles, seven coke fires taking No. 70 crucibles, and six coke fires taking No. 250 crucibles are used. One man can handle the five oil furnaces with No. 70 crucibles on brass and bronze. One man handles the three oil furnaces with No. 200 crucibles on manganese bronze, new metal, getting four heats in 11 to 12 hours from each furnace and sometimes an extra heat of scrap. Four men handle the 13 coke fires. No definite date on fuel consumption or metal loss are kept at present for the individual furnaces.

No. 70 crucibles last 30 to 35 heats; No. 250, 19 to 23 heats.

[The figures in subdivision 18 are on a test.] Under running conditions the percentage of metal unaccounted for in the foundry is 4 to $4\frac{1}{2}$; 1.5 per cent is recovered from refuse. The production consists of 40 per cent manganese bronze, 20 per cent

[a] Wyer, S. S., A treatise on producer gas and gas producers, 1901, p. 276.

white metal, and 40 per cent brass and bronze. We find the usual advantages for oil—speed, better control, no coke or ashes to handle. We find on the oil furnaces that a furnace working under 16-ounce air pressure is not so good for high copper alloys as one working under 4-ounce pressure [high pressure on the oil].

For natural-draft coke furnaces the stack should be at least 90 feet high, and the area of cross section of the main flue should be 1¼ times the combined area of small flues. The cross-sectional area of the stack should be 1½ times the combined areas of small flues, a proportion contrary to boiler practice.

Reply 21, subdivision 9.—Not using our heats to the highest efficiency prolongs the life of the crucible. The variation in melting losses in refining yellow-brass borings to ingot is too great to allow its accurate determination. A "feeder" [old crucible with the bottom cut out] is set into the top of the meeting crucible and the borings fed into it. A cover or flux of glass is used in melting.

Reply 22, subdivision 11.—The furnace has a diameter of 16 inches inside the lining. We have a special fire-tile lining made of four semicircular parts, the bottom circle being 4 inches thick and the top circle 3 inches thick. This gives the furnace interior a slight taper with the large diameter at the top. The furnaces are relined once every six months, but the lining is daubed with a mixture of fire clay and ground fire brick every morning. The grate bars are renewed about once a year. No other repairs are required. As we have a number of different mixtures, ranging from 90 per cent copper and 10 per cent tin down to 60 per cent copper and 40 per cent zinc, running at the same time, with no separate account kept of the losses of each mixture, we can give only an average from all of them, which varies in net loss from 1 to 6 per cent, depending upon the relative quantities of each mixture used. The average is about 3 per cent.

In the oil-burning, tilting furnaces without crucibles we have found from experiments that the melting losses due to oxidation run at least 50 per cent higher than in the regular pit furnaces; the metal is not as clean nor as good; the double pouring necessary with a noncrucible furnace gives extra expense in keeping intermediate pots hot and higher melting loss on account of having to get metal hot enough to offset the extra cooling necessitated by the double pouring; and there is also danger of pouring steam metal too cold, with the result of greater percentage of leakage at the test pumps. Therefore we have discontinued the use of other than pit furnaces.

Reply 23, subdivision 7.—We have made foundry tests on melting loss on our various mixtures and find that they run from an average of about 1.5 per cent in a high-grade red brass to about 5 per cent in yellow brass and manganese bronze. We of course recover the metal from our ashes and foundry sweepings, but distribution is not made in such a way that definite answers can be given. We have a number of standard mixtures, from a straight bronze containing 90 per cent copper and 10 per cent tin down to yellow brass and manganese bronze containing 30 to 40 per cent zinc. It is difficult to give an average. Our different mixtures are not run in separate furnaces or under separate conditions except as each particular crucible requires it. We believe that metal melted in a crucible is better and cleaner than metal melted in those types of furnaces in which it comes in direct contact with the flame. Aside from this broad division of furnace types the experimenting we have done has not been sufficient to warrant definite conclusions.

Reply 24, subdivision 12.—The proportion of sulphur in coke is 1 per cent; 72-hour washed coke is used. The coal moisture is 4 per cent; volatile matter, 5.5 per cent; fixed carbon, 77.5 per cent; and ash, 13 per cent.

The "pinch" type of crucible tongs is used.

Only one heat per day is taken. Eighty per cent of the fuel is coal on the bed, 20 per cent is coke around the crucible. Natural draft is used most of the time, the forced draft being used the last hour of the heat.

A few trials were made to melt manganese bronze in an open-flame, tilting furnace. Oil fuel vaporized by air pressure was used. We found it impossible to control the loss of zinc, and consequently the physical tests showed erratic results from the melts made in that furnace. No trouble in this respect is experienced with the type of furnace used at the present time.

Reply 25, subdivision 20.—Sixteen pit and two tilting oil furnaces are used. The pit furnaces are 15 inches in diameter by 26 inches deep; eight furnaces per battery, two batteries in all. The pit furnaces in each battery are grouped two on each side of a rectangle. They were originally built for using coke and therefore had ash pits underneath. Fuel oil is now used instead. Practically no modification of the furnaces was necessary to change from one to the other. The tilting furnaces are 15 inches in diameter by 18 inches deep. Oil consumption is not known, as oil meters are unreliable and the oil used here is for forges, furnaces, riveters, etc.

So far as we can determine, our furnaces give very satisfactory results. Oil furnaces are better and more economical than coke for the reason that the furnaces may be heated in shorter time and that the fuel may be turned off immediately when the heat is completed, whereas much of the heat content of coke would be used when not required. [No data were furnished on tilting furnaces.]

Reply 26, subdivisions 7, 13, 32.—A tilting coke furnace with air pressure of 4 to 5 ounces is a good furnace for sensitive metals, such as yellow brass, manganese bronze, or red metals; this furnace does good work, as one melter can get out five or six heats out of nine hours' work, with 400 to 500 pounds of metal to the heat.

The crucible used in this furnace is 22 inches long, 14 inches at the top, running to about 6 inches at the bottom. A good crucible runs 50 to 60 heats, the cost of the crucible being $20.

Our open-flame oil furnace is lined with silica fire brick; the cost is about $20; that is, lining and labor. This lining will last about two months. The openings on the furnaces have to be repaired every morning at a cost of 75 cents to $1. There are two oil burners, one in each end of the furnace, and from these we can get a very fine combustion in this furnace, but the melter must understand combustion. When this furnace is in proper order, it will give good results at a very small loss.

We can not use this furnace to melt yellow brass or manganese bronze, as it blows all the zinc out, but we can melt all kinds of red metal in this furnace. It has an air pressure of 12 to 14 pounds; the oil pressure is about 15 pounds. We can get six or seven heats per 9-hour day, with about 500 pounds to the heat, with melter and helper.

In the tilting crucible furnaces we find that a great deal of metal is melted from the top instead of from the bottom, which is detrimental to the metal. I have yet to find the first porous metal melted without a crucible in a rotary oil furnace. If a large quantity of metal is wanted, the oil furnace gets it out much quicker than the old-time crucible furnace; there might be a heavier percentage of loss in oil furnaces than in crucibles, but it depends a great deal on the metal being used. In melting in rotary oil furnaces it is well to have the furnace very hot before putting in metal.

Reply 27, subdivision 30.—The furnace is run only about 10 days a year.

Reply 28, subdivision 28.—The oil pressure is secured by forcing air at 70 to 75 pounds on top of the oil tank. Can push the furnaces and get four heats per day. A glass slag or cover is used on the metal. The crucible block has two V-shaped depressions at right angles to allow some heating of the bottom of the crucible. Tilting furnaces are better than pit furnaces.

Reply 29, subdivision 7.—Furnaces repaired every 125 heats.

Reply 30, subdivision 3.—A No. 60 crucible tilting furnace and a No. 40 furnace are used. The oil pressure is about 75 pounds; the air pressure about 60 pounds. Crucible life is 15 to 35 heats, according to annealing of crucible. Good flux will save metal and so will good furnace tender.

Old-time coal furnace turns out better metal all around. [A No. 60 tilting furnace is uncommon. The maker of the oil burner used usually supplies one taking a pressure of 30 pounds on the oil and 2 pounds or less on the air. An inquiry as to the correctness of the figures on oil and air pressure, metal loss, and oil consumption was unanswered. The metal-loss and fuel-consumption figures are evidently only estimates.]

Reply 31, subdivisions 32, 34.—Figures on gross melting loss include all foundry losses as well as mere melting losses. [No separate figures given for gas and oil.] The oil furnaces are not pushed to the limit, as with a hot furnace a heat can be gotten out in 45 minutes.

Reply 32, subdivision 2.—Pit furnace preferred.

Reply 33, subdivision 2.—We have no experience with other than coke furnaces.

We have no record of our percentage of loss during melting, as we do not keep any routine foundry records of daily heats. Our square furnaces are all of the one size, and require about the same amount of coke to charge a furnace for a No. 80 pot as for a No. 125 pot, minus the amount of space taken up by the larger pot; consequently we melt a No. 125 pot of metal cheaper than we do a No. 80 pot.

Reply 34, subdivisions 1, 28.—We are getting an average of about 19 heats from the No. 275 crucibles in the oil furnaces, and anywhere from 19 to 30 heats, depending on the make of crucible, from the No. 70 crucibles in the coke furnaces. From our point of view, as to the relative advantages and disadvantages in the two types of furnaces, much might depend upon the relative cost of fuel oil and coke, but thus far we find the quality of metal melted in the oil furnaces as good in every respect as that obtained from the pit furnaces. Our oil furnaces have been installed for a period of only about six weeks.

On the oil furnaces, starting with the cold furnace, the first heat in the morning this furnace will consume about 3½ gallons per hundredweight of metal; that is, red brass, containing 85 per cent copper, 5 per cent tin, 5 per cent lead, and 5 per cent zinc. The second heat will consume about 2½ gallons, whereas the third and remaining heats consume about 2.28 gallons per 100 pounds of metal melted.

Reply 36, subdivision 4.—[See remarks as to furnace tenders in notes on Reply 17.]

We have tried oil as a fuel, but find that the life of the crucible is very much less—so much so that we consider the use of oil inadvisable, especially since the price of fuel oil has increased so materially.

Reply 37, subdivision 30.—Our melt is about one-half red brass, one-quarter yellow brass, and one-quarter German silver. Fuel and loss figures are on all alloys, no separate records being available. We started out using a high air pressure on our oil burner and got much better results by reducing the pressure. With our present oil pressure and present type of burner, our air pressure is about as low as we can go.

The crucible life depends on the make of crucible. Our records show a life of 1 to 60 heats.

Reply 38, subdivision 2.—On 9 furnaces natural draft is used, with stacks 95 feet high and 30 inches inside diameter.

We have tried open-flame oil furnaces, crucible oil furnaces, and forced-draft, tilting, coke furnaces, and find that the pit fires give the best results in physical and hydraulic tests.

Reply 39, subdivision 32.—In our oil furnaces, the oil is forced by compressed air at 20 to 50 pounds; the blast is furnished by a low-pressure blower.

Our furnaces run three hours in the morning and three in the afternoon. We could get six or eight heats if necessary. Physically, there is little difference between metal from the open-flame furnaces and from others. Chemically, we find that we must use a crucible to get exact results.

We use 4.1 gallons of oil per hundredweight of finished brass castings. We also melt iron in this type of furnace, the melting ratio being 8.2 gallons per hundredweight of

finished castings. The amount of oil to melt the charge will be 25 to 30 per cent less, as this amount goes back as gates and sprues. This is not our best practice on this furnace, as we had some trouble during the month for which these figures are taken with poor oil and inexperienced furnace men.

Reply 40, subdivision 16.—We also use pit coke furnaces, with which one furnace tender can handle two to seven furnaces. We use 35 pounds of 72-hour Connellsville coke per hundredweight of melt.

The net loss on yellow metal is about 10 per cent.

Oil furnaces are more rapid than coal or coke, and not as much labor is required.

[This reply was noted on the question sheet and was returned without address, hence no inquiry could be made for more detailed information.]

Reply 41, subdivision 14.—Furnace should be lined every two months. There is no difference in the quality of metal from this and other types of furnace if the metal is not overheated.

Reply 42, subdivision 32.—This reply was noted on the question sheet and was returned without address; hence the small charge, which amounts to 286 pounds, or about 35 per cent of the rated capacity of the furnace, and the high oil consumption, could not be verified.]

Reply 43, subdivision 30.—The gross metal loss in melting is 6 to 5 per cent on castings. Allowing for remelt of gates, the loss on the charge itself is about 3 per cent.

An oil furnace in which the flame does not come in contact with the metal is much better than one in which it does. We have tried and discarded an open-flame furnace.

We are increasing our melting capacity, but are putting in new coal furnaces instead of oil furnaces, because of the high price of oil and the uncertainty of delivery.

Reply 44, subdivision 19.—[This reply was noted on the question sheet and was returned without address; hence more detailed information could not be requested.]

Reply 45, subdivision 16.—We have had as high as 54 heats from a No. 80 crucible. There is considerable recovery from slag, etc., but our records do not allow figuring this back to the original melt. Pit furnace, coke-fired, still used with No. 40 crucibles for certain work. Yellow brass and other light work. Unless ventilation is good, pit coke furnaces are the best. Oil furnaces cause sickness.

[Oil consumption given as 23 to 26 gallons per furnace per day; 2,400 pounds melted per day, or an oil consumption of 0.96 to 1.09 gallons per hundredweight of metal. A request for verification was unanswered.]

Reply 46, subdivision 5.—We get four heats per day per furnace. We could run six heats but do not need to do so, as our furnace capacity is more than required. The composition of our melt varies greatly on account of many mixtures used. Ordinary red brass is 85 per cent copper, 5 per cent tin, 5 per cent lead, and 5 per cent zinc. We use probably 35 per cent of gates. It is impossible to give accurate melting losses, as we do quite a lot of pigging up. Our total melting loss will average 4 to 5 per cent.

Our yellow brass is made entirely from scrap yellow brass, with the addition of 5 per cent of lead and 10 per cent of copper where necessary. We do not keep melting loss separate on red and yellow brass.

Have used only gas and oil furnaces outside of coke, and neither can compare to coke for our class of work, which is small castings almost entirely. Oil furnaces are exceedingly good for heavy red brass but not good for yellow. Gas furnaces cause greater loss and cost more than coke. Do not know about quality of metal, but any furnace that gives great loss by oxidation owing to excessive blast can not make good metal that has to stand pressure test.

Reply 47, subdivision 32.—We have other kinds of furnaces at our foundry, but the greater part of our work is done with the open-flame furnaces, and they are the only ones in connection with which we have made a series of tests. The other types are used only occasionally. The advantage of the open-flame furnace is the short time taken to melt and the fact that no crucibles are used.

Reply 48, subdivision 1.—One-fifth of our tonnage is on yellow brass, the fuel and loss figures for which are included. On yellow brass, using 20 per cent of borings, our gross loss is 7 per cent. We have just installed a forced-draft tilting coke furnace for making ingot from borings, but do not yet feel safe in using this on our regular work.

Reply 48, subdivision 7.—We have six sizes of furnaces, with dimensions as follows:

Inside diameter.	Height	Thickness of brick.
Inches.	*Inches.*	*Inches.*
13	25	3
14	28	3
15	31	3
16	31	3
17	31	3
20	31½	3

Sizes given are the sizes of the lining; outside of this lining is the sheet-iron drum. The lower half of the lining consists of a grout, made of carborundum fire sand, fire clay, old fire brick, and some salt.

The crucibles used range from No. 35 to No. 200.

One furnace tender can take care of 8 to 10 furnaces. We figure 100 pounds of coal to melt metal equivalent to 100 pounds of finished castings.

We get four heats per day on furnaces up to No. 100. These average three heats per day. Furnaces larger than this do not run regularly.

We have no data as to the frequency of relining furnaces. We have found this need to vary greatly, depending upon how the furnaces are forced. We have had as wide variations between relinings as 3 to 15 months. Minor repairs are made as needed but no record kept.

We average about 35 heats per crucible, sometimes running up as high as 40 to 42 on a No. 60 crucible.

We determine the net percentage by melting a given quantity of metal and pouring it in ingot form, thus eliminating all wastes and shop losses other than the loss by volatilization. Losses determined in this way average 3 per cent on new material, 5 per cent on all scrap material, and 8 to 10 per cent on all turnings. We find it possible to melt copper alone with no appreciable loss.

With our foundry running entirely on jobbing work, as it is, we have comparatively small opportunity for gathering data on furnaces except in a general way. The large number of alloys running and the irregularity in the heats is principally what compels us to adhere to the old style of pit furnaces, as they afford us more latitude for short heats, quick changes, etc.

Reply 50, subdivision 19.—Gravity feed system on oil from 60-gallon tank through ¾-inch feed pipe.

Reply 51, subdivision 1.—Each molder tends his own furnace.

Crucible life averages 34 heats; sometimes runs as high as 60, but very seldom.

The only other furnace we have had experience with is an oil furnace. We found that unsatisfactory because it gave out such dense zinc fumes that our men got the "shakes."

We also melt yellow brass. Fuel and loss figures include both red and yellow brass.

Reply 52, subdivision 16.—Analyses of oil: Flash, 180° F.; fire, 270° F.; cold, 25° F.; viscosity, 96 seconds at 100° F.

Find no difference as to the quality of metal, whether melted in coke or in oil furnaces. Main advantage of oil furnaces over coke is the saving in labor and cost of fuel. However, the cost of fuel in the oil furnaces is offset to a great extent by the additional cost of power required to run the blower. We have no way of judging the relative fuel consumption in our large and small furnaces. Twenty No. 45 crucibles

averaged 21.1 heats; maximum 31, minimum 14. Twenty No. 70 crucibles averaged 18.2 heats; maximum 24, minimum 14.

Reply 53, subdivision 1.—[This reply was noted on the question sheets and was returned without address; hence no more detailed figures could be obtained.]

Reply 54, subdivisions 16, 28, 32.—Our total melt runs 2 or 3 tons per day—about 2,500 pounds of No. 12 aluminum ingot, about 2,000 pounds of composition ingot brass, about 500 pounds of copper, tin, lead, and zinc (new metals), and possibly 1,000 pounds of borings, gates, and sprues.

We believe our melting loss averages about 3 per cent.

We consider the open-flame furnace a good furnace where large quantities of metal must be melted rapidly but do not consider it economical or conducive to a high grade of metal, etc.

We consider the crucible oil furnace a very good furnace, as regards the quality of metal and economy of operation, etc.; in fact we consider it the best on the market to-day; in the past six years we have made three separate trials of such furnaces in three different plants.

We are unable to give you definite information on the consumption of oil in the different furnaces, as we do not meter the furnaces separately. Our impression is that crucible furnaces are more economical as regards oil than open-flame furnaces, possibly from 15 to 20 per cent.

We believe that the No. 125 crucible is a great deal more economical than the No. 60, as both furnaces have the same burner, and it does not take a great deal more oil to melt the 350 pounds in the No. 125 than it takes to melt the 160 pounds in the No. 60.

The melting loss in the No. 125 and in the No. 160 crucible is about the same, averaging probably 3 to 3½ per cent, whereas the open-flame furnace averages 3½ to 4½ per cent.

Reply 55, subdivision 27.—Shape of our two furnaces, cylindrical; of two sizes: Outside diameters, 34 and 33 inches; heights, 33 and 28 inches.

Lining—fire clay, of two thicknesses: 2¾ and 1¾ inches.

Gas used is from wells on company's property; it is not metered. Number of heats, 4 on aluminum, 2 on brass.

Furnaces relined once a year and repaired whenever necessary.

Heats to life of crucible, 16 on brass, 40 on aluminum.

We melt aluminum, red brass, manganese bronze, and gear bronze, all consisting of about 75 per cent new metal (including gates) and 25 per cent of old metal.

Reply 56, subdivision 11.—Our experience covers furnaces using three kinds of fuel, namely, anthracite coal, coke, and crude oil.

As far as results are concerned, the only reason we give preference to furnaces using anthracite coal over furnaces using coke is because the former occupy much less room, a consideration of vital importance in our location. Our experiences with furnaces using crude oil were very unsatisfactory for two reasons:

First, because of the fumes from the oil itself. Our foundry has excellent ventilation, but in spite of this, we seem unable to force the fumes or vapor from the foundry room.

Second, our business is such that we are required to produce alloys of very accurate proportions, and in most instances we found it impossible to do this with the crude-oil furnaces. An alloy containing a certain proportion of tin or zinc could not be maintained, owing to the fact that the flames from the oil burner seemed to burn out the tin or zinc and to melt the copper only.

Reply 58, subdivision 21.—Our furnace holds two No. 35 crucibles. The capacity is three heats in 10 hours, but we seldom run more than two. The furnace is square; inside dimensions about 4 by 4 feet by 3 inches; fire-brick lining. We use only one side. We get about 650 pounds per day, melting gates; 350 pounds, melting borings; have only one furnace. [Data not clear.]

Reply 60, subdivision 17.—Eighty-foot chimney on 15 furnaces. One melter is taking care of 15 furnaces with a helper part of the time. The watchman starts the fires.

We find that we have less trouble with crucible metal than with any other. Open-flame furnaces also used; with a careful furnace tender we can get as good metal from these as from pit furnaces. The castings from metal melted in the open-flame furnaces stand up as well on hydraulic test. [No data on open-flame furnaces.] Open-flame furnaces used chiefly for ingoting scrap. Have to have 12-ounce air pressure on open-flame furnaces to get the metal out in a reasonable time. "Grab" tongs are used.

Reply 61, subdivisions 17, 31.—Loss figures are lumped for coal and oil and for red and yellow brass. Bad castings are apt to be slightly higher from the coal than from the oil furnaces. Oil furnaces with the burner above, pointing downward into a combustion chamber, are somewhat better than those fired from the bottom. Oil vaporized by steam at the burner.

In one type of furnace a No. 125 crucible lasts 45 heats; in another, in which the crucible is not supported at the bottom, it lasts 42. Oil-furnace figures lumped for both types.

Reply 62, subdivision 12.—We have tried a gas furnace, but found that we would have to have gas for not over 30 cents per 1,000 cubic feet, whereas our city gas costs $1 per 1,000 cubic feet. We also have found that our metal loss is considerably greater from oxidation, and therefore have gone back to our pit furnaces.

Reply 63, subdivisions 13, 28, 32.—Castings made from metal melted in crucible furnaces show a slight superiority on both physical and pressure tests. There is no apparent difference as to behavior in foundry, although tilting furnaces without crucibles show a higher melting loss and a larger percentage of defective castings, owing to oxidation. They are more economical because of the low cost of lining as compared with the cost of crucibles.

The reason that we get a lower fuel efficiency out of the larger open-flame furnace than from the smaller furnace is that the average charge in the large furnace is not as near to the full capacity as in the small furnace; for example, the average charge for the large furnace of 2,000-pound capacity is 1,750 pounds, four heats being run in one day, and for the small furnace of 1,000-pound capacity the average charge is 917 pounds, six heats per day being run.

Reply 64, subdivision 1.—We use principally scrap, consisting in a large part of yellow brass; one furnace tender can handle only five furnaces, and then by no means easily.

Our gross loss on both red and yellow brass (yellow brass is 65 per cent copper, 30 per cent zinc, and 5 per cent lead) is 9 to 10 per cent; the net loss is about 5 per cent; it is not determined accurately. On red metal the average net loss is close to 3 per cent.

Reply 65, subdivisions 2, 32.—[In reply to an inquiry as to the low figure for oil consumption, this firm replied: "We find that the figures given you for oil consumption are correct and should stand, as they represent what we are actually doing every working day under normal conditions."]

Reply 67, subdivisions 31, 32.—Open-flame furnaces are patched every day. The furnaces are the same size for the No. 40 and the No. 80 crucibles, and there is but slight variation in the amount of coke used for the No. 40 and the No. 80.

Reply 68, subdivision 6.—Our metal must needs be heated to a high temperature in order that it may be carried in the crucibles to the various molds, as we are able to pour as many as 36 molds from one No. 35 crucible of metal on some of our light jobs. We use a furnace designed by ourselves which utilizes the waste heat in the primary furnace as it passes through a secondary chamber on the way to the flue. In this secondary chamber we can run down to a molten condition two charges of red brass and sometimes four charges of yellow brass, while we are bringing up the metal in the

primary fire to the necessary pouring temperature. The primary furnace is 4½ feet deep, and lined up square, 14 inches in diameter, with fire brick about 9 inches between the fire space and the steel shell of the furnace. The ash pit is closed so as to give a forced draft under the grate bar.

We have tried three types of oil furnaces: First, an open furnace, which we did not like on account of the great amount of fumes thrown out in the foundry and on account of the effect of the flame coming in direct contact with the metal, which apparently so affected it that it would not run in our small light castings. We next tried a portable oil-burning furnace, supposed to move around the foundry on a track. This furnace was so constructed that the crucible was not removable and the flame came in contact with the metal as it did in the ordinary open-flame furnace; the results were about the same. We also experimented with a stationary oil-burning furnace in which the crucible was removable, but each time came back to the coal and coke burning furnaces.

[A special tall crucible 9½ inches in diameter and 17 inches high is used. The metal is poured very hot, almost at the boiling point. The furnace tender pokes the metal with an iron rod, and not until he can feel the metal "jump" when stirred is it considered ready to pour. The castings are so light that there are 2 pounds of metal in gates and sprues to 1 pound of castings. A thick fuel bed is used. Both coke and coal are used, but it was stated that coal alone would probably give better results, although the cost would be higher. The furnaces had been built round, but have lately been rebuilt in square form. The fuel consumption in the square form was stated to be considerably greater per hundredweight of melt than in the round furnace. The difference was ascribed to the employment of a less careful furnace tender. The square form was built mainly because the operator wished to use a form of tongs having trunnions that fit into bearings on the pouring shank, so that the metal carriers can stand upright while the molder tips the crucible to pour the metal. The projecting trunnions on these tongs would not allow their use in the round furnaces.]

Reply 69, subdivision 30.—Oil furnaces, as compared with coke furnaces, have a greater output, require less labor and attention and less room, use cheaper fuel, and are cleaner. Their disadvantage is that they burn out the zinc; consequently we have to add 2 pounds of zinc to every 300 pounds of metal.

Reply 70, subdivision 2.—Loss figures include red and yellow brass. Loss on yellow brass runs from 10 to 5 per cent in refining borings.

Square furnaces are used to give room for tongs.

We have never tried the other improved furnaces but have watched with interest the experiences of others and have never found their results to have been sufficiently successful to warrant our making a change from the old-style pit furnace, as we have always found the metal made in this way to be of a better quality in every direction.

Reply 71, subdivision 7.—We are using the pit furnace. Have used a tilting oil furnace with crucible and open-flame oil furnaces. We found from actual test that the crucible pit furnace answered our purpose much better, as we can handle the metal to better advantage as to temperature and shrinkage.

The net percentage of loss on yellow brass, with an average analysis of 67 per cent copper, 30 per cent zinc, and 3 per cent lead, is about 4 per cent.

We have tried several makes of furnaces, including the crucible tilting oil furnace, and two forms of open-flame furnaces. Our experience has been that the open-flame furnaces can be handled very successfully on composition mixtures, but on yellow brass we did not have such good results. We have also found that the operator is a very important feature in successfully running these furnaces. The crucible, tilting, oil furnace gave fair results, but on account of the excessive cost of fuel oil we found the crucible pit furnace was better suited to our requirements.

Reply 72, subdivision 2.—We use pit coke furnaces, but from our experience we believe that on our class of work the best results can be obtained from either a gas

or an oil furnace of the crucible type, preferably arranged for tilting, as on this type of furnace the melting loss is lowered; it is more simple to get material at a proper heat, the life of the crucible is much longer, and attendance is less; although we can find no difference in the quality of the metal either on physical or pressure test.

We are herewith inclosing a copy of our daily melting sheet, which is a fair example of the way our melt runs.

[In this day's run, with 55 per cent of new metal, 30 per cent of borings, and 15 per cent of gates, the gross loss was 3.5 per cent. On yellow brass (70 per cent copper, 30 per cent zinc), with one-third each of ingot, gates, and borings, the gross loss was 9.4 per cent. The fuel consumption on the total melt, of which 55 per cent was yellow and 45 per cent red brass, averaged 69 pounds of coke per hundredweight of melt, or 50 per cent more than was given in the body of the report as the average figure.]

Reply 73, subdivision 32.—This furnace has two egg-shaped chambers placed end to end. The figures given consider both chambers as one furnace.

Metal from the open-flame oil furnace is as good as from a coke-fired crucible.

Reply 74, subdivisions 2, 4.—Square furnaces are used to make room for tongs. Gross melting losses: Gun metal 1 per cent, red brass 1½ per cent, half yellow and half red brass 2 per cent, yellow brass and manganese 2½ to 3 per cent.

Oil furnaces have been tried and discarded. The forced-draft tilting coke furnaces give the same quality of metal, but the melting loss is higher, although the coke consumption is lower than in natural-draft coke furnaces. Most forms of tilting coke furnaces stand so high in the air as to make charging and coking hard on the furnace tender.

Reply 75, subdivisions 1, 16.—We use two grades of metal: Yellow brass consisting of 2 parts of copper to 1 of zinc, and red brass consisting of 82 to 85 per cent of copper, 4 per cent of tin, and the balance zinc and lead. The loss figures cover both, as separate figures are not available.

At the present price of fuel oil it is somewhat cheaper to melt by coke than it is by oil, but on the other hand we can get out a good deal more metal with oil. We have not found any difference in quality of metal.

We did not find the burner supplied with our oil furnaces satisfactory and have changed to one using low-pressure air and high-pressure oil.

Reply 76, subdivision 1.—[Fuel and loss figures are rough approximations and not based on records.]

Reply 77, subdivision 1.—[The accuracy of the fuel and loss figures is doubtful. During a visit to this plant by the author the foreman stated that the fuel consumption was 70 to 85 pounds of coke per hundredweight.]

Reply 78, subdivisions 3, 28, 32.—The open-flame furnace is seldom used and then only in an emergency. It was used for one entire day in the last two months; the furnace received a charge of 710 pounds of "compo" brass, and a loss of about 140 pounds resulted. The advantages of melting brass in oil-burning furnaces has been questioned by numerous foundry men, and I am of the opinion that circumstances, locality, nearness to the fuel markets, and transportation facilities have a peculiar bearing on this matter, but aside from that I am sure the best results in making steam-tight work has been by the use of coke-burning furnaces.

The oil furnaces melt quicker in some respects but only in the melting of light "compo" or brass have they equaled the coke furnaces. It is cheaper to melt with coke than oil, when you consider the extra cost of piping and the heavy loss of crucibles.

Our oil furnaces are not giving the results anticipated when they were installed. The coke furnaces have proved their superiority over oil-burning furnaces in making steam-tight work, such as high-pressure valves, condenser heads, etc.

Probably under a fan-blower system instead of high-pressure air the results from the oil furnaces may be more satisfactory than at the present time. No pressure tests have been made, but a number of physical tests have been made to make compari-

sons and decisions. No appreciable difference in the tensile strength or the bearing qualities of each metal. [On a visit to this plant it was found that the oil burners in use did not properly vaporize the oil and admitted too large a volume of air in the effort to vaporize it, giving an oxidizing flame. Moreover, in the crucible furnace the flame was pointed directly at the base of the crucible and the oxidizing nature of the flame cut away the crucible, causing the low life. The burners on the open-flame furnace are in similar shape and have not been run under proper oil and air pressure. This will at least partly account for the poor showing of the oil furnace.]

Reply 79, subdivisions 8, 13, 15, 28, 32.—The metal (68 per cent of copper and 32 per cent of zinc) from the square. tilting, forced-draft, coke furnace is poured into a ladle and then into a slab or billet mold, 40 by 14½ by 1⅝ inches, at about 1,850° to 1,900° F. Analysis shows an average zinc loss during melting of not over 0.5 per cent.

The advantages of the natural-draft furnaces over other furnaces used at this plant are the quality of metal produced, the small melting losses, and the carrying off of obnoxious gasses; these gases are carried through the stack, thus relieving the shop of a great deal of the obnoxious fumes that would otherwise be spread, causing great inconvenience to the workmen. A furnace man has greater opportunities to watch his metal and to see that it is at all times covered with charcoal, thus shielding it from oxidation.

One of the disadvantages (if it is a disadvantage) is the length of time required to run a heat down. The cost of fuel may be slightly higher, but when consideration is given to the amount of metal produced in one day by one furnace man and a helper, in comparison with that produced by other furnaces used here, it is not so high.

It is true that other furnaces get a greater number of heats per crucible. If the crucibles of the natural-draft furnaces were treated in the same manner as those of the other furnaces, probably there would be a greater number of heats per crucible; these crucibles after being used all day are dumped on the floor and are allowed to cool in the temperature of the shop; they are not put back into the furnace and allowed to cool off gradually with the furnace, as the crucibles of the coke and oil furnaces are allowed to do.

Another great advantage of the natural-draft furnaces is the small space a battery would occupy in comparison with the oil or coke furnaces. In the shops where large bronze castings are made—that is, castings weighing 10,000 to 17,000 pounds or more—it would be almost impossible to use the coke or oil furnace, owing to the space a battery large enough to melt sufficient metal to pour the casting would occupy.

In all probability the forced-draft coke furnace is the next best, as far as the quality of the metal and economy in fuel are concerned. The heat can be run down in a very short space of time, making this class of furnace good to follow up a molding machine on some classes of work.

One advantage it has over the natural-draft furnace is the small amount of ashes to be cleaned out. It seems to consume nearly all the fuel.

One of the disadvantages is the obnoxious gases that are thrown out into the shop. Another is that the furnace man is not able to keep a good watch on his metal; also the furnace does not bring down the metal hot enough to pour all classes of work without recoking the furnace; when this is done, it has no advantage over the natural-draft furnace as to time required to run a heat down. These furnaces are hard on the furnace man. He is not protected at all from the heat emitted from the furnace while he is recoking it. On account of the forced draft the wear and tear on the crucible and lining is slightly greater than that of the natural-draft furnace.

The oil furnace has the advantage over the other furnaces that it is easier to handle, requiring very little attention; there are no ashes to handle and no cost for removing ashes. The furnace is not hard on the furnace man; he is protected from the heat at all times. In charging the furnace, he has only to shove the ingot of copper into the crucible as these ingots are laid on top of the furnace. One of the disadvantages

is the obnoxious gas that is thrown out into the shop; another is the roaring noise that is made by the blower. The cost of fuel is higher than with the coke furnace, making the cost of production a little greater than with the coke furnace.

The cutting of the crucible and lining are greater than with the coke furnace, as the pressure is greater.

In regard to the fuel efficiency of the large coal-fired pit furnaces being less than that of the smaller ones, the loss of efficiency of the large furnace was probably due to the condition of the furnace. Both furnaces were in poor condition and in need of repairs. There was not time to put these furnaces in first-class condition for the tests; the two used were taken at random from a battery of 16. It is thought that both furnaces would have made a much better showing had they been in first-class condition. The tests were made as if they were on the regular work. There were no special efforts made.

The shape of these furnaces, whether round or square, is a matter of opinion; some claim the circular furnace is the better of the two; both have their advantages and disadvantages. The square furnaces have been used in our foundry a number of years with good results. It is true they require more fuel than the circular furnace and probably the heat is not quite as regular as in the circular furnace. Some claim that the pocket in each corner of the square furnace is an advantage in that it is much easier to place the tongs on the crucible to remove it from the furnace. The fire is much easier "chunked down" in a square furnace. The circular furnace does not require as much fuel, and the heat appears to be more even. The foundry here had no experience with the circular furnace, owing to the fact that the square furnaces have always proved satisfactory and have always yielded good results.

Shape and dimensions of the reverberatory oil furnace for melting scrap are as follows: This furnace is oblong, 4 feet 6 inches wide, 8 feet long, and 7 feet 6 inches high. The melting chamber is lined with fire brick. It is 13 inches high from the bottom of the furnace to the crown, at the charging end. It is 3 feet 4 inches high and 3 feet wide at the back end. The runner is 0.21 inch from the floor line to the bottom of the runner. The metal is charged at the front end, and the tapping-out hole is located on the side.

This reverberatory furnace is a standard make with a rated capacity of 2,000 pounds. We overcharge it about 50 per cent. There are two burners used, with an air pressure of 27 pounds per square inch. The furnace is charged with heavy scrap; the turnings and skimmings are charged from time to time until the full amount of the charge is in the furnace. The furnace is preheated about one and a half hours before the charge of metal is placed. The second heat is charged while the furnace is still hot. About two and a half hours is required for the first heat and about two hours for the second heat. Between the first and second heats, the time required for charging and making ready is about one hour. The time required from the time the furnace is lighted until the end of the last heat is seven hours.

We reline this furnace on an average of once in 11 months. It is run almost constantly, being run for four months, two heats per day, then shut down for three weeks or a month. The average number of heats per lining is 200.

It does not require the entire time of four men to handle this furnace. The furnaceman cares for the furnace and has everything in readiness for the helpers to charge the furnace. It requires two helpers to charge the furnace and the other helper is used to help pour off, when the metal is down. It requires about 15 minutes to pig the metal.

[As an example of a complete report of a comparative test, the following from Reply 79 is presented:]

Details of practice with five types of furnaces in a given foundry.

Item.	Large, natural-draft, coal furnace.	Small, natural-draft, coal furnace.	Crucible, tilting, oil furnace.	Crucible, tilting, forced-draft coke furnace.	Reverberatory oil furnace with two burners.
Diameter or inside dimensions	31×31	27×27	34	36	54×96
Height, inches	43	36	27½	32	79
Thickness of fire-brick lining, inches	4¼	4¼	6¾	5	8
Kind of cover	Cast iron.	Cast iron.	Fire brick.	Fire brick.	....
Diameter or dimensions of cover, inches	25×25	22×22	27½	32	....
Depth of covers, inches	3½	4	3	4	....
Thickness of fire-brick lining of covers, inches	2	2	3	4	....
Size of flue, inches	8×10	7×7	....	....	....
Height of ash pit, inches	24	19	....	19	....
Width of ash pit, inches	22	20	....	32	....
Length of ash pit, inches	42	27	....	....	....
Size of crucible used	No. 200	No. 80	No. 275	No. 225	....
Life of crucible, number of heats	12	16	22	21	....
Moisture in fuel, per cent	4.16	4.16	....	....	....
Volatile matter in fuel, per cent	3.10	3.10	....	2.50	....
Ash in fuel, per cent	10.57	10.57	....	11.50	....
Sulphur in fuel, per cent	....	....	....	0.9	....
Specific gravity of fuel	....	....	0.9105	....	0.9105
Analysis of fuel, °B	....	....	24	....	24
Analysis of fuel, B. t. u. per pound	12,960	12,960	[a] 19,350	12,750	[a] 19,350
Fuel used	Egg coal.	Egg coal.	Crude oil.	Coke.	Crude oil.
Blast pressure	....	....	20 ounces.	2 inches of water.	27 pounds.
Heats run before relining furnaces	300	450	....	....	200
Length of working day per furnace, hours	7	7	7¾	7¼	7
Total metal charged per furnace, pounds	1113.5	724	3228.5	3016.5	6565
Nature of charge	New metal.	New metal.	New metal.	New metal.	Scrap.
Metal loss per day, pounds	6.75	4½	13½	19¼	328½
Gross losses, per cent	0.61	0.62	0.42	0.64	5
Copper in metal charged, per cent	90	90	90	90	88
Tin in metal charged, per cent	7	7	7	7	5.5
Zinc in metal charged, per cent	3	3	3	3	5.0
Lead in metal charged, per cent	....	....	1.55	1.55	1.5
Elastic limit of alloy produced	16,807	14,769	14,769	15,278	....
Tensile strength of alloy produced	47,798	42,883	42,831	42,831	....
Elongation of alloy produced, per cent	65.90	30.58	34.70	20.05	....
Reduction of alloy produced, per cent	64.24	34.40	35.36	24.31	....
Number of heats	2	3	5	5	2
Metal charged in first heat, pounds	556.75	251.5	711	611	3,740
Metal charged in second heat, pounds	556.75	251.5	702.5	600.5	2,825
Metal charged in third heat, pounds	....	221	704.5	600	....
Metal charged in fourth heat, pounds	....	....	710.5	605.25	....
Metal charged in fifth heat, pounds	....	....	400	600	....
Total metal charged per day, pounds	1,113.5	724	3,228.5	3,016.75	6,565
Losses in first heat, pounds	3.5	1.25	3	4	187
Losses in second heat, pounds	3.25	1.50	2.75	4.5	141.5
Losses in third heat, pounds	....	1.75	2.75	3	....
Losses in fourth heat, pounds	....	....	3	3.25	....
Losses in fifth heat, pounds	....	....	2	4.5	....
Total losses per day, pounds	6.75	4.5	13.5	19.25	328.5
Fuel used in first heat, pounds or gallons	259	100	19.75	213	41.6
Fuel used in second heat, pounds or gallons	144	51	12.5	113	31.4
Fuel used in third heat, pounds or gallons	....	53	11	107	....
Fuel used in fourth heat, pounds or gallons	....	....	11	118	....
Fuel used in fifth heat, pounds or gallons	....	....	7.75	130	....
Total fuel used per day, pounds or gallons	394	203	62	681	73
Metal melted per pound or per gallon of fuel, pounds	2.8	3.1	52.1	4.43	90
Average time of first heat, minutes	[b] 181	[b] 132	[b] 120	[b] 106	....
Average time of second heat, minutes	[c] 183	[c] 87	[c] 78	[c] 70	....
Average time of third heat, minutes	....	114	69	64	....
Average time of fourth heat, minutes	....	....	72	70	....
Average time of fifth heat, minutes	....	....	45	68	....
Time taken to clean furnace, minutes	2	2	....	3	....
Average metal per minute, pounds	3.04	2.17	8.4	7.97	15.63
Number of furnaces one furnaceman can attend	8	10	2	2	1
Metal produced, pounds	8,908	7,240	6,457	6,033	6,565

[a] 145,600 B. t. u. per gallon. [b] Furnace cold at start. [c] Furnace hot at start.

[The above results show again that the losses on gun metal from new material can, with care, be kept below 1 per cent. The results of this test are cited in full, because of its completeness—measurement of the draft on the natural-draft furnaces, analysis of the flue gases, and measurement of the temperature to which the metal was heated, being about the only omitted details that would have given useful information.]

Reply 80, subdivisions 7, 32, 37.—The reverberatory furnace is 8 feet 8 inches long by 5 feet 8 inches wide, 3 feet 4 inches high at the sides, and 4 feet high at the center [inside measurements]. The furnace is lined with fire brick to a thickness of 1 foot 4 inches on the walls and 9 inches thick at the door end. It has a sliding oval-shaped door, 3 feet 8 inches by 2 feet 4 inches and 5½ inches thick, made of cast iron and lined with fire brick 3½ inches thick.

In this furnace the oil is under a pressure of 20 pounds, and three burners, furnished by the maker of the furnace, are used. The air pressure is supplied by a pressure blower at a pressure of 16 ounces. The furnace is used only occasionally, and then only for large castings. It takes three men about 1½ hours to charge it; after that one man handles it.

The furnace uses between 2½ and 3 gallons of oil to 1 hundredweight of brass melted. This is on a single heat from a cold furnace and would be reduced if the furnace were in constant use.

Both the open-flame and the reverberatory furnaces are usually allowed to cool down for an hour or so at the end of 4 hours' melting in order to preserve the lining. The furnace is so seldom used that no accurate data can be given as to the length of time the furnace may run without relining.

The furnace is rated at 10 tons, but to date it has never been necessary to make anything larger than a 5-ton casting from this furnace in one melting. Gates, sprues, borings, and other scrap, are used whenever the nature of the casting will permit, the amount of new metal being kept down to the minimum. Compositions are made according to requirements.

Metal melted in a crucible furnace gives the best tests. In connection with the metal melted in the reverberatory furnace, in which, owing to the air blast, it is not always possible to make a reducing flame, at times considerable oxidation of the castings has resulted.

The loss in the two makes of open-flame furnaces on yellow-brass scrap is 5 per cent. The pit furnaces are intended for a No. 60 crucible; No. 25 and No. 100 crucibles are sometimes used.

Eight thousand pounds of red-brass borings was run down in a cupola usually used for iron. Four hundred pounds of coke was used on the bed, then the borings, with 960 pounds of coke in the charge. A very mild blast was put on for 1½ hours, after which the metal was poured into ingots. Seventeen pounds of coke per hundredweight of borings was used. The metal loss was 8 to 10 per cent. There seemed to be no trouble due to absorption of sulphur from the coke, though no analysis of the metal was made for sulphur. With the addition of 25 per cent of new metal, the ingots were satisfactorily used for making pump castings.

Reply 81, subdivisions 32, 33, 38.—The crucible furnace is a safe one as far as the metal is concerned, but for our work is entirely too slow.

We will take a No. 150 crucible, put it in the pit fire, and it will take anywhere from 2½ to 3 hours and the loss runs from 3 to 4 per cent. Now take the space for coke and the extra labor of handling the same as well as the loss of crucibles. From experience we find the open-flame furnace far ahead. We can melt 1,000 pounds of red or yellow brass in one hour with 30 gallons of oil, where in the pit we would use about 600 pounds of coke and would require the extra handling of ashes after heat was drawn. The disadvantage of the egg-shaped, open-flame furnace is that it throws the fumes and gases into the shop and is detrimental to the health of the men. The lining is a little troublesome. Owing to the shape and position, the overhang is apt to fall in once in a while,

but for speed in melting and keeping the metal in good condition, I consider the furnace excellent for general work.

The spherical, tilting furnace is worked on the same principle as the egg-shaped one. Its advantages over that are the better lining; that is, it stands up better; being of brick it consumes a little more oil and is not so fast.

When we want first-class valve metal, we always use this type of furnace. We have tried all our furnaces on tests of some kind, but we found the open-flame furnace the best for pressure tests, such as valves from one-fourth inch to 10 inches. We tried a forced-draft, tilting, coke furnace, with crucible. We had the same man who now runs our spherical, open-flame furnace run it for 7 hours, 6 heats, 400 pounds each heat, but he was a very tired man. With the open-flame furnace he can take out 3,000 pounds in 5 hours and feel in good condition at the end of the day's work.

One good point about the spherical, open-flame furnace is that it does not blow the fumes out into the shop. Owing to its shape and position, the long pouring spout can be kept under the hood at all times. Another great advantage the oil furnace shows over the crucible and pit furnaces is that there is some assurance of getting your metal when you want it. From experience, we can tell how long it will take to melt a certain amount, whereas the pot of a crucible often leaks when you are ready to pour. I consider the oil furnace the cheapest as regards the physical condition of the metal. I have seen tests taken from crucible metal which did not compare with the oil-furnace product. No matter how you melt, whether in oil furnace or crucibles, if the pouring is not done at the proper temperature, the alloy will be poor, as each alloy requires different treatment and to be poured at different temperatures to suit the class of work in hand.

Our reverberatory furnace is oil fired. It has an oblong furnace door 11 feet wide, 13 feet long. It has a 7-ton capacity. The walls are of fire brick, 24 inches thick; the floor is a layer of brick covered with 1 inch of foundry sand wet with clay water, and is cleaned for each different alloy. The door is 4 feet 6 inches by 3 feet 6 inches, with a small door in the center, 13 by 18 inches for charging turnings, of cast-iron lined with brick. Three low-pressure air burners are used, high-pressure burners having been discarded.

One furnace man with a helper is required. This furnace is used for melting down miscellaneous scrap. It has not been relined in 3 years. We use a sand floor for each different alloy. Fourteen thousand pounds is melted per heat. Miscellaneous scrap and about 20 per cent borings is the composition of the melt. Red brass, yellow brass, manganese bronze, and high-tin bronze, as well as general scrap for ingots, are produced from this furnace. It melted 600 tons of different alloys without repairs to brickwork.

The reverberatory fuel-oil furnace compared with the natural-draft, coal furnace, shows up way ahead in all respects. Over half the time, labor, fuel, and floor space is saved.

We will take a heat of 10,000 pounds, consisting of 50 per cent of heavy scrap, 30 per cent of light scrap, and 20 per cent of borings, tapped in 1,000-pound lots and poured into ingots for analysis. Three hours will be consumed from the time of starting to the finish of work. One furnace man and a helper can look after this heat, the charge being put in the furnace the day before the melt. In a case of this kind the heavy metal is put in the furnace when it is cold, so that the larger door may be removed, as we oftentimes put in a piece weighing 1,500 pounds, which must be handled with bars. When the heavy charge is melted, the borings are shoveled in through the small door and pushed into the bath.

This furnace has run since July, 1909 [reply dated Nov. 27, 1912], and melted 600 tons of all kinds of compositions for ingots and large castings, such as circulating pumps, main condensers, and gear wheels, which show well on tests. The only repairs made to date consisted in the making of sand floors about 1½ inches deep.

In the case of the natural-draft furnace there are the grate bars to be replaced, the ashes to be removed, and the floor of about 2 inches of sand to be made up. If 100 tons of alloy were melted in this furnace it would be in bad shape, whereas the oil furnace is very well braced by stay bolts and metal sheathing.

A great advantage of oil furnaces is that when fluxing you can put the flux in the bottom of the ladle and then pour the metal, which then mixes better than with the crucible, in which there is a great loss because the flux has to be pushed through the metal, as in the use of phosphorus.

Reply 82, subdivisions 1, 28, 37.—We burn Connellsville coke, for which detailed analyses are not available, and natural-draft furnaces, vacuum not known, are used. The stack is 84 feet high and 31 inches inside diameter; it accommodates 19 pit furnaces.

For ordinary brass-foundry work the pit furnace is far superior to the tilting or reverberatory furnace. The losses are small and therefore the quality of the product more uniform and reliable. With care and skillful operation the product of the reverberatory furnace is as reliable as that from the pit furnaces. The greater time element for the pit furnace is not a serious objection. For running down turnings and miscellaneous scrap the pit furnace is superior.

Our reverberatory fuel-oil brass furnace is rectangular in horizontal plan, being 7 feet wide and 9 feet long, shallow at the rear and deep at the front; roof arched from side to side and also from front to rear; tapped from the front into a pit. Lining, fire brick, 6 inches thick, with sand bottom.

Entire front face removable for extensive repairs; door with peek hole in removable section; cast-iron sections bolted together and lifted in one piece; lined with fire brick. Specifications state that oil shall have a specific gravity not greater than 0.9465 (18° B.) at 60° F.; the oil pressure is 15 pounds and the air pressure 140 pounds at the throttle. Patent burners of the high-pressure closed type are used. It takes one man a full day, or two men two hours, to charge.

This furnace is used almost entirely for running down scrap, such as large castings or tubing; for this class of work it is excellent. In one case where analyses were made of a large propeller that was run down, zinc was added to make up for the volatilization; there was no difference in the analyses before and after such addition.

As to our tilting oil furnace with crucible, the data are based on less than a dozen heats. The only advantage of this type of furnace is the rapid melting which may be obtained. These furnaces have not been used for two years.

Reply 83, subdivisions 4, 31, 33, 38.—The natural-draft pit furnaces used Lehigh anthracite coal of best quality, clean, dry, and free from slate, bone, dirt, pyrites, and other impurities, and Connellsville 72-hour coke of the following analysis: Specific gravity 1.8, or not less than 1.75; moisture 0.42 per cent, not to exceed 1 per cent; volatile matter 0.80 per cent, not to exceed $1\frac{1}{2}$ per cent; fixed carbon 87.46 per cent, not less than 86 per cent; ash 11.32 per cent, not to exceed 13 per cent; sulphur 0.69 per cent, not to exceed 0.80 per cent; phosphorus 0.015 per cent, not to exceed 0.03 per cent.

The draft is estimated to be about 0.25 inch of water.

The answers aside from those for the reverberatory are based on the regular output of brazing metal, gun bronze, aluminum zinc, Muntz metal, scrap brass, white metal, naval brass, manganese bronze, and various other special compositions. The losses are lumped for all alloys on all the furnaces aside from the reverberatory.

The coal and coke pit furnaces and the crucible oil furnaces are used for all work requiring special physical characteristics and pressure test. The open flame is used for yellow brass and small fittings. The reverberatory is used for heavy manganese bronze castings.

Satisfactory metal can be produced from either the coal and coke or the oil crucible furnaces, the coal and coke furnace showing the highest efficiency in operation and a more uniform product. The crucible oil furnace is used as a reserve in case it is neces-

sary to reline the pit furnaces or make repairs on the stack. It is hard on crucibles, and losses are considered to be somewhat higher than in the case of pit furnaces. A heat in the crucible oil furnace takes six hours with cold furnace and three hours with heated furnace. In the open-flame furnace it takes one and one-half hours with cold furnace and one hour with heated furnace. The reverberatory takes six hours with cold furnace. The losses in melting in the other furnaces are comparatively small compared with that with the open-flame furnace, in which the flame comes in direct contact with the melt. In the case of yellow brass and manganese bronze, the losses in the open-flame furnace are largely due to the volatilization of the zinc.

A test on the reverberatory furnace at the time of its installation showed a loss of 3.62 per cent when melting a charge of 2,540 pounds of manganese bronze. In this furnace the flame is reverberatory and the charges are comparatively heavy. In the crucible furnaces, the metal being in the crucible, the flame does not come in direct contact with the same and the loss is comparatively small, being not more than 0.5 per cent in the case of composition.

Thelosses in melting yellow brass and manganese bronze in furnaces of the open-flame type will approximate 6 to 7 per cent.

Reply 84, subdivision 32.—Crude oil is piped from tank about 25 feet from furnace, forced up to furnace by air pressure, and heated by steam before entering burner. Air comes from positive blower. Air pressure in No. 1 furnace, 12 ounces; in No. 2 furnace, 15 ounces; down draft. Specific gravity of oil, 0.96 at 15° C. (California oil).

We have no regular amount per day, as it depends on what work we have to pour. We melt from 300 to 1,500 pounds per day with our No. 2 furnace, and from 300 to 1,000 pounds with our No. 1.

The coke-fired pit furnaces are best for particular mixtures, as there is less chance for oxidation and consequently less loss in melting and in casting. We have excellent results with open-flame furnaces. If there is any difference in the metal, it does not show in the physical tests. All of our heats are tested and analyzed.

Reply 85, subdivisions 5, 28, 33.—The advantage of the crucible type of oil furnace is that it is compact, easy to handle, and radiates little heat. The disadvantage is that the life of crucible is short. Our furnaces are used only intermittently.

Reply 86, subdivisions 19, 31, 33.—In the spherical, open-flame furnaces it has been found best to keep the auxiliary cover closed, depending upon the pouring spout entirely for the escape of gases. A recent test of the oil used gave the following results: Gravity of oil freed from water, grit, etc., at 60° F., 17.3° B.; specific gravity 0.9505; percentage of water 0.42 per cent; percentage of grit, etc., 0.34 per cent; calorific value of 1 pound of pure oil with water vapor due to hydrogen content uncondensed, 17,605 B. t. u.; same, water vapor condensed, 18,790 B. t. u.

One man handles all three spherical open-flame furnaces, makes necessary repairs on linings daily, and cares for the ladles used in carrying the metal to the molds.

No reliable data on oil consumption are at hand. Oil for entire foundry passes through one meter only. It is estimated that it takes 1 gallon of oil to melt 50 pounds of metal in the open-flame furnace.

Linings in the open-flame furnaces have been known to last for two years, but 18 months is more nearly the usual life of the lining, and constant attention is nessary to make them last for that length of time. Inspections are made daily and repairs made as found necessary.

The open-flame furnaces are used successfully in the manufacture of all the general run of composition castings, but can not be depended upon for castings subjected to very high pressures. For castings requiring high tensile strength, or that must withstand high pressures, the crucible seems the only reliable furnace. The open-flame furnaces of both types can be run more economically and efficiently than the pit or crucible furnaces.

In the egg-shaped open-flame furnace the oil used is same as described for the spherical furnace. The air is supplied from a high-pressure line; the pressure used at the furnace is not known, being regulated by the attendant. The pressure of oil at the burner is from 17 to 20 pounds, the exact pressure not being known.

The burners are of the air-atomizing type; two are used, one at the center of each end of the double chambers. The chambers being joined at the center, the jets from the burners mingle and combustion is made more complete thereby.

The class of melting done by these furnaces, reducing scrap to ingots, requires the services of two men, one to attend the furnace, the other to handle the miscellaneous scrap. It is estimated that 1 gallon of oil will melt 50 pounds of metal in this type.

These furnaces are used almost exclusively for melting scrap metal, and are used intermittently. There are, therefore, no reliable data regarding relining. They are carefully watched and repairs made as found necessary.

In the tilting crucible we estimate that 1 gallon melts 50 pounds of composition metal; for babbitt, 100 pounds per gallon of oil is melted. We have no means of determining exact amount used.

We get three heats of composition, or eight to ten of babbitt metal. For melting babbitt, the crucibles last so long that no data are at hand regarding the number of heats they will stand.

These furnaces are used almost exclusively for the manufacture of babbitt metal and are seldom used to the limit of their capacity. The maximum amount of babbitt that can be melted in one day of eight hours is 2,600 pounds, using both furnaces, one melting 100 pounds each heat, the other 160 pounds, ten heats being taken off. This metal is made from the original Babbitt formula: 88.8 tin, 7.5 antimony, and 3.7 copper.

The fuel used in the tilting-crucible furnaces is not definitely known. It is estimated that 1 gallon of oil will melt 50 pounds of metal. One heat only is taken off in a day from these furnaces. These furnaces are used only for melting manganese bronze, gun and valve metal when required in quantities exceeding 1,200 pounds, their principal service being in the casting of propellers, propeller hubs, and sleeves for propeller shafts. Their use is therefore infrequent and the lining lasts indefinitely.

The large crucibles are used so infrequently that no definite data are available by which to determine the number of heats that may be taken from them.

The capacity of the small furnaces is 750 pounds each, using crucible No. 275; the large furnaces use crucibles No. 600 having a capacity of 1,800 pounds each. Manganese bronze, gun and valve metals are the only ones melted in these furnaces.

The principal losses are due, in the melting of manganese bronze, to escape of zinc and losses due to slopping of metal when being handled by the crane. In handling gun metal the loss is due to slopping of metal. The amount recovered is very small, and as it is recovered as part of the general miscellaneous waste in the shop, no definite data are obtainable. It is estimated that the loss due to melting manganese bronze is about 6 per cent. In the melting of gun metal, the estimated loss is 4 per cent.

We have two square and two round, pit, oil furnaces. Square ones 19 by 19 by 27 inches; round ones 16 inches in diameter by 27 inches deep. Round furnaces made so by filling up corners of square ones. Nos. 30 and 100 crucibles used. The quantity of fuel used in these is not definitely known. Supposition is that 1 gallon of oil melts 50 pounds of metal. The heats are irregular in quantity and kind of metal used and no reliable data can be given. No data on losses can be given. The losses when metal is melted in pit crucibles are very small; supposed to be less than 2 per cent. No yellow metal is made from the pit furnaces. Used for phosphor bronze, gun and valve metal. No average can be given.

Reply 87, subdivisions 2, 4.—Nos. 45, 70, and 100 crucibles are also used in the smaller furnaces, and run from 25 to 30 heats on red brass.

The stack is 70 feet tall for 22 furnaces. The gross loss on red brass is estimated at 2 per cent, on manganese bronze one-third to one-half ingot, two-thirds to one-half gates, 7 to 10 per cent. We average 45 pounds of coke per hundredweight of metal on red brass; 50 pounds on manganese bronze. "Pinch" tongs are used. Square furnaces are used because of the ease of firing and of repairs, also because they give room to get the tongs down in the furnace. A heat can be gotten out more quickly with small coke than with large.

Reply 88, subdivision 19.—Have had experience only with pit furnace using coke and with oil furnaces. Find oil is cheaper than coke and gives better results all around. Data given are those obtained by writer when trying out an oil furnace with view of replacing pit coke furnaces with oil furnaces.

After a few hours instruction on previous day from representative of furnace makers, I lit the furnace at 7.35 a. m.; put metal in at 7.44; took first pot out 9.32, second at 10.44, third at 11.53; furnace stood idle until 1.05 p. m.; took fourth pot out 2.30, fifth at 4.05, and sixth at 5.05. Nine hundred pounds was melted, all being new mixture of red metal; 18.8 gallons of oil was used.

On the following day the furnace was lit at 6.56 a. m., the first pot was removed at 9.11, second 10.28, third 11.53, fourth 1.02, fifth 2.09, sixth, 3.14, seventh 4.17, eighth 5.10. Seventy per cent new mixture, 30 per cent gates; 1,480 pounds melted. I ran the furnace personally for nine days until the crucible gave out, melting 9,085 pounds in 58 heats, using 2.13 gallons oil per hundredweight melted. Furnace lit 81.44 hours. In the above run the pouring pot was heated in pit furnaces. Following above we put in pot heater and oil burner on core oven. In the operation of the furnace for nine days I discovered a number of things which I thought would add to the life of the crucible, and which proved out in a later run of three months during which time I had a melter in charge of furnaces, but gave them careful watching personally, with results as follows: In March, April, and May 192,580 pounds metal was melted, 6,511 gallons oil was used, or 3.38 gallons per hundredweight melted. This includes all oil used for baking cores, pot heater, waste, etc. The average number of heats per No. 60 crucible during this time was 71½; highest, 82 heats; lowest, 52 heats.

After the melting had been left to the melter, our average number of heats per crucible dropped to 61 for the following three months. The oil used was crude oil as pumped through a Pennsylvania pipe line. In 1909 we were troubled with so much sediment and water in oil that we changed to light-colored fuel oil, which we purchased in tank cars. Before making this change in oil our crucibles would not last as long as was customary, and I tried a number of makes, but have been unable to get as good results, and have been unable to locate the trouble outside of the crucible itself. We are now getting only 35 to 51 heats on No. 60; 25 to 35 on No. 125. We did have one recently that went 41.

Reply 89, subdivision 7.—We run very light castings; hence require hot metal, and the metal is often held in the furnace for some time after it is ready to pour, waiting for molds; hence the high fuel and loss figures.

We have a foreman who used to use a cupola for large melts, with hard coal as fuel, but he can give no figures on fuel consumption or metal losses.

Reply 90, subdivision 14.—A "feeder" is used, and the air is preheated by passing around the furnace shell through an outer casing. The crucible is a tall conical form of English crucible. The 450-pound size lasts 45 heats, and the 150-pound size, in a proper sized furnace, lasts 55 to 60 heats. The fuel consumption in the 450-pound size is 15 pounds of coke per hundredweight of metal; in the 150-pound size, 20 pounds. We reline the bottom part of the furnace every 1,000 heats. The upper part lasts longer. A comparative test of a crucible, tilting, oil furnace against this type showed a melting loss of 5.03 per cent in the oil and 4.90 per cent in the forced-draft, tilting, coke furnace. The oil consumption is 2.8 gallons per hundredweight.

Our loss in running down chips to ingot on 100,000 pounds was 6 per cent.

Reply 91, subdivision 33.—We have displaced our pit coke furnaces by the open-flame with entire success. Our castings have to stand high pressure. We have tried the forced-draft, tilting, coke furnace, which can not compare in economy with the open-flame. We also tried out a rectangular-pit, oil furnace with one burner, a dozen crucibles being set into the pit. The heats took so long that the loss was great, the oxidizing flame scored the crucibles badly, and their life was short, and the furnace was hard on the tenders. We have abandoned this type of furnace. We use charcoal and salt, skimming off the slag and putting it back with the next heat. Our pouring crucibles are preheated in a pit, coke fire; it takes 250 pounds of coke to heat pouring crucibles to handle the pouring of 6 tons of metal.

Reply 92, subdivision 32.—We are also melting brass in crucibles by natural draft, using coal for fuel. The life of these crucibles is about 16 to 18 heats.

[Note that small heats—only one-fourth the rated capacity of the furnace—are made, with good fuel efficiency. No figures were given on metal losses.]

Reply 93, subdivision 18.—It has never been necessary to reline any of the furnaces that we have ever installed. Occasionally we go over the brick linings with a solution made of carborundum fire sand. This seems to work very satisfactorily in preserving the brick. We have a number of these furnaces that have been in constant use for five or six years.

The fuel-oil furnace has proven much more satisfactory than the ordinary coke furnace and the stoker type of furnace using coal as fuel. One of the good features of a fuel-oil furnace is the low shrinkage. It requires much less labor to operate this type of furnace. A crucible will last much longer. We do not believe there is any material difference between the metal melted in a coke and that melted in a coal furnace. We have never made any tests in this respect but we feel that conditions favor the fuel oil owing to the fact that the heat is much more uniform.

The consumption of oil per hundredweight of metal melted when No. 50 and No. 60 crucibles are used is practically the same as when the No. 80 crucibles are used.

When the No. 50 and the No. 60 crucibles are used in the oil furnaces that we are now using, the volume of flame around the entire crucible is much larger than when a No. 80 crucible is used. This results in getting more heats per day with the smaller crucible with practically the same total weight of metal melted.

With reference to the stoker type of furnace, using coal for fuel, they did not work out very satisfactorily. Our main trouble was to get a brick lining that would withstand the heat produced by this furnace; as the cost of upkeep was very high we threw out this entire equipment.

We regret that we are unable to give you any information with reference to the fuel consumption per hundredweight of metal melted as well as the loss in shrinkage as we destroyed all of these records.

The type of stoker furnace we tried was so arranged that a number of crucibles could be set on the fire at the same time. There were openings in the floor through which the crucibles were put into the furnace. These openings resemble the ordinary furnace pits of the regular type of coke furnace commonly used by a great many foundries. We are of the opinion that this type of furnace is not used to any great extent; in fact, the writer is of the opinion that the manufacturer has discontinued making them.

[The manufacturer wrote as follows: "The stoker type of furnace which we installed at ——— was a failure. We have not done anything with it for the past four or five years."]

Reply 94, subdivisions 5, 25, 18, 33.—The open-flame furnace gives more of a loss in melting, the flame coming in contact with the metal. The crucible furnaces give better results, on account of flame not coming in contact with metal, making the oxidation less, and making the mixture of metal more uniform. The open-flame furnace is not in use much; only for red-metal mixtures. To get same mixture on

yellow casting we must charge 10 to 15 per cent more zinc to overcome the excessive loss. The loss in this furnace on red brass is 2.1 per cent.

We have run the gas furnaces only a few days.

Reply 95, subdivision 10.—[See notes on Reply 17 as to furnace tenders in rolling mills.] We have experimented a little on a 5-ton reverberatory furnace [probably fired with producer gas] but have not yet gotten it to the point where it is satisfactory. About 1 per cent of the melt is recovered from the ashes. The reasons why rolling mills so generally use the square furnaces instead of the round are shown in our experience which has been as follows:

It is necessary for us to have a certain space between crucible and furnace walls in order to put tongs on the crucibles. With the square furnace we utilize space on corners for this. We can therefore use a square furnace having less horizontal area than that of a round furnace that would give us room to adjust tongs. The quantity of coal contained in the square furnace is enough to melt the charge; consequently the extra coal in the round furnace would be burned without helping much to melt the brass. This is in line with our experience that the coal consumption is less in square fires. Also, as the heats we use are high, and our furnaces must be relined frequently, it is desirable to have a simple form of lining and to use standard-shape fire bricks, which are cheaper.

Sand-casting shops pour their metal at a lower heat than we do and also have less bulky scraps to melt. It requires considerable coal for us to raise the heat of our brass above the heat at which sand-casting shops pour.

Regarding melting in larger quantities, the objection has been the difficulty of handling large quantities. We are not able to pour into ladles and thence into molds on account of having to pour at high heat.

Reply 96, subdivision 32.—This is a double-chamber furnace. Lining is of an asbestos, high-temperature cement, about 6 inches thick.

Using this cement, furnaces require relining about every six months, according to grade of metal melted. There are cases where it runs more or less. Repairs are made, such as daubing around charging hole, on an average of three times a week, or as often as required to keep furnace in good shape.

Reply 97, subdivisions 1, 24, 30.—No. 60 and No. 80 crucibles are used. Forty-eight-hour coke is used for pit furnaces—gas and oil for tilting furnaces. Natural gas, under a 6-ounce pressure; air, under an 18-ounce pressure. Three furnaces per tender. Fuel consumption, 139 cubic feet of natural gas, 2.8 gallons of oil, or 255 pounds of coke per 200 pounds of metal. Four heats per day. Working day, 12½ hours. Patched once per month. Crucible life, 23 to 28 heats.

Charge per furnace per day, 900 pounds: New metal 294 pounds, turnings 160 pounds, gates, sprues, and scraps 446 pounds. Gross loss, 3 per cent. Loss in foundry from all causes, 2.8 per cent. Yellow brass and red metal melted.

We don't find much difference in furnaces; both satisfactory.

[A request for more detailed information to allow tabulation of data for the different furnaces was unanswered.]

Reply 98, subdivision 28.—The net loss is uncertain; we estimate it at ½ per cent. Fuel oil is superior to coal; the general appearance of castings is better and other conditions are more satisfactory.

We also use egg-shaped, open-flame furnaces, in which we estimate an oil consumption of 1¾ gallons per hundredweight of melt. No data on losses.

Reply 99, subdivisions 12, 33.—We find we get less loss from porousness on hydraulic tests, and metals pour better from pit furnaces.

Reply 100, subdivisions 20, 31.—Our net loss is 3½ per cent. This percentage may seem pretty high, but we have no mechanical means for recovering brass from the slag, dross, etc., but recover some of this by getting a good price for the refuse when

we sell it, and no account has been taken of that. The number of heats from a No. 125 furnace and also the No. 45 furnace depends upon the kind of metal used. A heat can be run down quicker if all ingot is used than when scrap, such as screw-machine turnings, clippings, etc., is used. On our work, which is almost all the latter material, the larger furnaces require more labor than the small ones. We do not keep the time separately, but we have three men to take care of 12 furnaces and one man looks after the two large ones and does some work on the small ones. The average weight of a heat in the tilting furnace is about 350 pounds, in the small ones about 130 pounds.

The life of a crucible in a tilting furnace, other things being equal, is longer than that of crucibles in the pit furnace when the crucibles are removed with tongs.

In regard to the amount of oil used in each furnace, we have no way of knowing, as the oil is all taken from one main lead pipe, and we have never measured individual furnaces.

Reply 101, subdivisions 1, 13.—There is no difference between the metal from the pit and that from the tilting, coke furnaces. In the tilting furnaces we lose 6 to 10 per cent on yellow-brass turnings.

Reply 102, subdivisions 16, 28.—Our furnaces are designed to use either gas, oil, or coke. Oil is used at the present time. We have stopped using the tilting furnaces, the pit furnaces doing away with the oxidation due to the double pouring when metal is transferred to a ladle.

We are using low-pressure air and high-pressure oil in the oil burner, which is much better than the burners using high-pressure air.

Reply 103, subdivision 16.—The furnace is cylindrical; top 26 inches, bottom 32 inches in diameter; inside depth, 16½ inches; outside depth, 2 feet 5 inches; depth of cover, 4½ inches, lined with fire brick approximately 5 inches thick.

Reply 104, subdivisions 33, 35.—The figures on speed of melting in the natural-gas, open-flame furnace are from special tests. The normal speed is less than the normal speed when the furnaces are oil fired. If we drive the furnaces we can double the normal speed [given in the table] on the oil-fired furnaces.

The melting loss with natural-gas firing is about 10 per cent greater than with oil, so we have gone over to oil, although we formerly used natural gas very largely. The better results with oil firing are due to greater speed in melting.

The borings are put in the bottom of the furnace, gates on top of these, and the ingot on top of the gates. We have tried briquetting the borings under very heavy pressure, forming them into rather solid blocks, but the melting loss of the whole charge, put in as above stated, was decreased less than 0.1 per cent figured on the total charge, which did not pay for the briquetting. On charges of all borings results might be better, but no such tests were made.

In order to get a low melting loss the open-flame furnaces must have the lining kept smooth. On the top and sides of the furnace we use a fire brick much used in blast furnaces, and a cementing material of German fire clay, 1 part, and ground ganister, 3 parts. This is swept into place by a revolving templet.

It is best not to rock the furnaces during the melt, as this increases the oxidation. We reduce the size of the pouring spout so as to keep as high a pressure in the furnace as possible. The metal melted in the open-flame furnaces is equal in quality to that melted in other types.

Reply 106, subdivision 17.—We have tried building these furnaces in a vertical, cylindrical shape, but could note no advantages over the square ones; as they were harder to construct, we ceased to build them that way. For combustion we use blower air at low pressure.

In regard to fuel-oil consumption on the basis of gallons per hundredweight of metal melted, we have run a couple of tests on this basis. Although at the time the tests were run we were not getting the highest efficiency from our fuel oil, we found that

it took about 8 gallons of oil to melt 100 pounds of metal. Our experience shows that the net percentage lost in melting is less than 1 per cent.

Reply 107, subdivision 7.—[Subdivision 7 shows "average analysis of product" instead of analysis of a single alloy. Reply states: "Average net loss on yellow-brass scrap 6 to 10 per cent."]

Reply 108, subdivision 25.—The furnace is of the recuperative type and is built in two sizes to accommodate a No. 50 or a No. 100 standard crucible. The recuperative and pit settings are placed in a sheet-iron shell, the bottom sheet being reinforced by two **I** beams. The crucible pit is formed by an inner ring of circle fire brick, 4½ inches thick, and an outer ring of brick 2½ inches thick. Between the two is an annular space about 2 inches wide, filled with asbestos-fiber insulation. The furnace is provided with three air-blast burners, to which the air and gas are brought through separate pipe rings. Each burner is made with an inner and outer tube, the mixture of air and gas taking place at the tip of the burner. The three burners are placed 120 degrees apart and are inserted into special burner tile provided at the bottom of the inner fire-brick ring. The axes of the burner are tangential to a circle whose diameter is slightly smaller than the diameter of the crucible pit, thus insuring a perfectly reverberatory action of the three flames. The flames enter the pit below the bottom line of the crucible, so that there is no direct action of the flames upon any part of the crucible. In this manner all burning of holes into any part of the crucible or any uneven heating is avoided, lengthening materially the crucible's life. The inside surface of the pit is lined with high-temperature cement lining 1½ inches thick. The crucible is placed on a removable, circular bottom block. A cupola-type drop bottom, which can be released from the operating floor, permits prompt dumping of the furnace in case of failure of a crucible.

A waste-gas flue connects the crucible pit with the recuperation chamber, which consists essentially of a suitable brick setting and five cast-iron recuperator sections. The sections are provided with ribs to increase the radiation surface and have three compartments to prolong the time of contact of the air with the radiator surface heated by the waste gases. The cold air from the blower enters the last section in the furnace and passes through each successive section and out of the first into the air ring that supplies the burners. A displacement of 288 cubic inches of air per revolution, when operating on an air pressure of 2 to 3 pounds, is customarily used. The power required to run it is about 1½ horsepower.

Better control of heat in the gas furnace means cleaner castings and less loss; small oxidation seems to go with sound castings, a result especially noted in thin or difficult work.

Several analyses were made of the waste gases by means of an Orsat apparatus. The results of these analyses indicated the presence of a slight trace of carbon monoxide, never, however, exceeding 0.4 per cent, besides, of course, the proper proportions of nitrogen, water vapor, and carbon dioxide, results that show absolute control of gas and air regulation, bringing about perfect combustion, and hence fuel economy. An examination of the hot crucible after the test showed that the highest temperature existed at the bottom, insuring melting of metals from the bottom up, an essential requisite with the foundryman. The temperature of the waste gases at the exhaust flues was about 200° F., indicating the efficiency of the recuperation. Loss of heat from radiation was negligible, as the temperature of the outside of the shell was little above the room temperature.

It is almost impossible to operate an oil furnace with a reducing flame, on account of the excessive amount of air that must be forced into the furnace to increase the rapidity of melting. To obtain a reducing flame, it is necessary to have the right proportions of air and oil, as the oil should be sufficient to burn up the amount of oxygen that is forced into the furnace. This is almost impossible as the oil and air pressure are continually varying and the valves can not be regulated to get the right

proportions. Therefore too much or too little oil and air are allowed to enter the furnace. This condition necessarily results in imperfect combustion, hence fuel waste. The waste-gas analyses in the above test show that practically perfect combustion of gas existed throughout, after the mixture of gas and air had once been regulated. The importance of this factor in melting can not be overestimated.

Aside from the effect upon castings, perfect or imperfect fuel combustion has a decided bearing upon prolonging or shortening the life of a crucible. The most serious effect in the use of oil is at the start with new crucibles. With an excess of oil entering the furnace, there being too little air to form perfect combustion, the surplus moist oil gases will be forced against the crucible walls, producing what are known as "alligator" cracks, and layers will peel from the crucible to a depth depending upon how far the moisture from these hot oil gases has penetrated. On the other hand excessive air produces an oxidizing condition, which extracts the carbon from the crucible wall, leaving a porous-clay structure. Although the wall may retain its original thickness, the graphite has been taken away, and the crucible is ready to crack, its vital substance having disappeared. Again, owing to the arrangement of the burners, described above, the gyrating motion of the flames in this gas furnace is more perfect; hence the heat distribution is more even than in the case of the oil furnace, where a single burner is used to obtain these effects. The result is a uniform heating of the crucible walls, allowing them to expand equally as the temperature rises. In this manner all local strains in the crucible walls due to uneven heating are avoided. Another cause tending to shorten the life of crucibles, and one freely admitted by operators of the old-style coke furnaces, is the difficulty experienced by the furnace tender in taking hold of the hot crucible with the tongs, preparatory to lifting it from the furnace for pouring. Frequently the rocking and jarring of the crucible with the tongs, necessary to penetrate the closely packed incandescent coke in order to get a firm hold of the crucible, results in prematurely cracking the crucible, or in what are known as pinhole leaks. That this difficulty is obviated in the use of a gas furnace is self-apparent.

[This reply and the data were furnished by the gas company supplying the gas to the foundry, not by the foundry itself.]

Reply 109, subdivision 8.—We use 100 pounds of hard coal and 2 hods of charcoal to melt 150 pounds of metal.

Reply 110, subdivision 7.—Round furnaces give more uniform heat [than square ones] and are best for all purposes.

Reply 113, subdivision 1.—In my 32 years' experience in brass foundries I find a vast difference in brass-melting furnaces. I find that the old pit coke furnace, with the new grates and double-bottom plates, are the best in the long run; properly handled, they produce the best results, and the least shrinkage of any furnace of other makes and fuels; when you put your metals and mixtures into the crucible, you can depend on getting the results, barring two things, overheating or a leaky crucible.

Pit furnaces with crucible, and oil or gas fuel, come next in my estimation and experience. A furnace in which the oil or gas burns directly over or in and about the metal is the poorest furnace, as there is too much shrinkage and loss of metal—the lead, zinc, and tin burns too easily and too fast, and consequently the mixture has changed in melting, and the quality is not the same as we get from pit furnaces. I have never tried to find out the difference by physical tests—only in machining and colors, and there is a vast difference there.

Reply 114, subdivision 1.—Oil furnaces are fit only for common heavy work, such as car bearings, ingots, etc. Coal or coke furnaces are the best for cheapness and fine results.

Reply 115, subdivision 11.—We do not know how many furnaces one tender could handle, as we operate only three.

It is reported to the office that the life of a crucible is about 45 heats, but we do not guarantee this assertion. It is only a short time since our foundry was a one-man

foundry. There has really been no system upon which it has been run, and it is only within the last month or so that we have been in a position where we could even think about getting a definite line on its workings.

Reply 117, subdivision 31.—The furnace is of an elliptical shape. The dimensions are: Height 4 feet, width 3 feet, length 4 feet 9 inches. The opening for the crucible is round.

We find the oil furnace a decided improvement over the hard-coal or coke furnace. There are no skimmings to become mixed with the coal or coke. When a crucible breaks in a coke or coal fed furnace there is a decided loss. When it breaks in a tilting, oil furnace the loss is nominal, as the molten metal may be poured out immediately.

The tilting, oil-burning furnace saves the labor of one furnace tender and eliminates much heat, dirt, and floor space. In addition, the fuel is nearly one-half cheaper. It is also much easier to charge a tilting furnace.

We obtain a much more even heat and a stronger and more even metal by mixing it all at one time in place of mixing it in several smaller pots.

In watching one furnace a tender may give greater care than to several, eliminating chances of burning the metal.

Reply 118, subdivision 10.—We estimate 154 pounds coal for 2 heats from a No. 30 crucible. We used 32 tons of coal to produce 32,202 pounds of yellow-brass castings (exclusive of gates and sprues).

Reply 119, subdivision 1.—Our furnace pit is made of concrete and is 44 feet long, 9 feet wide, and 7 feet deep, with 12 ordinary coke furnaces with drop grates of our own design and make.

All the furnaces are circular and all of the same depth; three sizes of diameter to take No. 40, 60, and 80 crucibles. We allow about 4 inches on the sides for the coke. The lining is fire brick, about 4 inches thick.

We use 72-hour Connellsville coke, egg size. Natural draft is furnished by a round brick chimney about 60 feet high, 3 feet at the base and 2 feet at the top. The smoke tunnel leading to the chimney from the furnaces is 2 feet wide and 3 feet deep.

We believe three furnaces are all a furnace tender can attend properly. We have no data on the consumption of coke.

We believe that a natural-draft coke furnace is the better furnace for getting out specific alloys in smaller quantities, and with an experienced furnace tender the loss in melting can be held lower because the heat is better regulated. On the other hand, if heavy castings are to be made, like railroad journal boxes and bearing boxes of any kind, which require big weight in metals, we believe an oil furnace is the best, because of the larger quantity of metal which can be melted. Our experience, however, is that a forced-draft oil furnace is too expensive and too wasteful to be of any use for melting yellow brass, as the loss of zinc is too great. An oil furnace also has its place in a city where floor space is high; but in a smaller town where floor space is cheap we believe that the natural-draft coke furnace is the best.

Reply 120, subdivision 24.—We used in 1912, 56 No. 40, 117 No. 50, and 18 No. 60 crucibles. Heats per crucible averaged 10.8.

Advantages of gas are ease in starting, absence of dust and ashes. Can notice no difference in the quality of metal.

Reply 121, subdivisions 1, 28.—We are using both coal-fired pit furnaces and oil-fired tilting-crucible furnaces. We have six pit furnaces at present, but we contemplate doing away with part or all of these in the near future and substituting either oil-fired or coke-fired furnaces. We are also considering an electric-heated furnace of new design.

We used to use an ordinary fire-brick lining, but are now using, with considerable success, a lining consisting of fire brick, faced with a mixture of carborundum and kaolin,

with water-glass binder to a depth of about 1½ to 2 inches; double thickness of wall, 6 to 6½ inches. We use about 85 per cent of carborundum in the mix.

We use No. 125 pots in the tilting furnaces and No. 40, 60, and 80 pots in the pit furnaces.

One furnace tender and a helper handle all the furnaces that are operated daily. Generally three of the tilting furnaces are going at one time and at least two of the pit furnaces.

To date we have never made enough tests on fuel consumption to warrant giving figures. Recently we made some tests on one of the tilting furnaces that seemed to indicate that we were using more oil than the claims of the manufacturers demanded. It would be perhaps advisable to test the consumption on more than one furnace before any figures are given.

The working day is 10 hours. Occasionally one or more furnaces are started an hour earlier in the morning, if production demands such procedure at the time.

The pit furnaces are relined on the average once in six months. The oil furnaces are refaced about once in three months.

In the pit furnace the life of the crucible ranges between 20 and 30 heats; in the oil furnace, between 10 and 18 heats.

Our alloy list contains about 20 different mixtures, of which about one-half dozen are cast in rather large quantity.

We cast four alloys in which the copper runs above 80 per cent, which includes our scrap alloy above referred to and several types of gun metal. We also cast aluminum and one or more of its alloys, as well as bearing metals.

The only furnaces we have tried are those that are now in operation. We have never tested bars poured from both types to determine the comparison between the metal taken from each.

Reply 122, subdivision 9.—[This reply was noted on the question sheets, without address.]

Reply 123, subdivision 3.—Coke furnaces are best for high-zinc alloys.

Reply 124, subdivision 20.—We find that the crucibles do not average so great a number of heats in the oil furnaces as in the coke furnaces.

Reply 126, subdivision 1.—Stack 65 feet high.

I have had the most uniform brass, with the least percentage of loss, both in metal and in castings, when using good coke not too high in sulphur. Oil fuel oxidizes the metal more than coke, which makes better pressure-tight castings. Never made physical-test comparison. Get a more uniform temperature with coke, owing to operator's inability to judge the metal accurately in an oil furnace.

Reply 128, subdivision 7.—We find coal the best.

Reply 132, subdivision 7.—There may be other good furnaces, but when you are required to produce a bronze to analyze similar to the Government requirements, with a tensile strength of 30,000, an elastic limit of 15,000, and an elongation of 15 per cent in 2 inches, you can not better the results obtained from the crucible or pit furnace.

Reply 134, subdivision 16.—A home-made burner is used, consisting of an oil nozzle with a ½-inch outside diameter and a $\frac{1}{16}$-inch hole in the end, which is brought down in conical form. Around this nozzle tube and concentric with it is a tube of ⅝-inch inside diameter, which carries compressed air to aid in atomization of the oil. Around these tubes and concentric with them is a 1½-inch tube carrying a low-pressure fan blast, furnishing air for combustion.

We use scrap car brass with one-eighth new copper. We use the slag again on the next heat. We charge first the light brass, then the new copper, with a special flux [the active agent of which is probably manganese dioxide], then the old slag and sprues, and then scrap journal bearings. Our gross loss is 6 per cent, which is very small, as we use crushed charcoal on the top of the charge. We make two 1-hour heats a day,

using 80 pounds of metal per heat; 2 gallons of oil used per day per burner. [This would amount to less than 1.3 gallons per hundredweight, a figure that is doubtful.]

Reply 135, subdivision 3.—We use 25 pounds of coke per hundredweight when the furnaces are new; when the lining is worn thin, about 33. A good deal depends on the weather.

Reply 136, subdivision 19.—The oil is preheated before entering the burner.

Reply 137, subdivision 3.—Tried city gas at $1 per 1,000 feet, which was too expensive.

Reply 139, subdivision 7.—Stack 60 feet high, 18 inches in diameter.

Reply 140, subdivision 10.—[See notes on Reply 17 as to furnace tenders in rolling mills.]

We have 25 fires on each stack. Stacks are 100 feet high and 3½ feet in diameter. The length of heat on a No. 70, No. 80, or No. 90 crucible, coaled up to the top, and each in the same sized furnace, is the same; that is, the fuel consumption in the larger crucible is less per hundredweight of metal melted. We are going to try round furnaces the next time we line any up.

Tests on losses on yellow brass with all new metal gave 2.5, 3.1, and 1.8 per cent. On a test to see the effect of holding the crucible in the fire too long we got 2 per cent loss when the crucible was in the fire 7 minutes after speltering, and 4.7 per cent loss when it was held 22 minutes after speltering.

We sometimes use a little coke if the pot "hangs" [does not melt down with normal rapidity].

We have tried open-flame oil furnaces for melting yellow brass, but had too much zinc loss, and the metal poured from them could not be rolled cold, although it could be rolled hot. We calculate that 1 to ½ per cent of the total melt is recovered from the ashes.

[The crucible is set in a pouring shank, which is mounted on trunnions, and is tilted by a handwheel and gearing, the whole being mounted on a truck that is pushed on a track laid beside the pit in which the ingot molds are set. The truck and crucible are then pushed along till the lip of the crucible is over the gate of the mold, when the metal is poured by means of the handwheel, the diameter of which is at right angles to the course of the track. Pouring is as steady and as rapid as in ordinary practice with a rope hoist. The man pouring is out of the zinc fume, as is his helper, who skims the metal with a long skimmer. He is also protected from the heat by a shield placed between himself and the pot, but not cutting off his view of the lip and gate.]

Reply 141, subdivision 10.—[See notes on Reply 17 as to rolling-mill furnace tenders.]

We tried an open-flame, oil furnace on yellow brass. No trouble was found in pouring into a ladle and from that into the molds, but the zinc loss was too high.

Reply 142, subdivision 1.—On yellow brass (76 per cent copper, 20 per cent zinc, 1 per cent tin, 3 per cent lead) our loss averages 4 per cent.

Reply 143, subdivision 7.—We use three scuttles of coal to melt 150 pounds.

Reply 144, subdivision 28.—The average life of a crucible is 18 heats, with a maximum of 38 and a minimum of 4.

The recovery of metal is considerable from slag, skimmings, etc., as we are using a cinder crusher, recently installed. The gross percentage of loss during melting averages 6½ per cent. The net percentage of loss remains to be determined when we have had the cinder crusher longer in use, and have secured some records from its operation. It is now operating on an accumulation of several months.

Previous to the installation of these oil-fired, tilting-crucible furnaces, we used pit fires, but discarded them on account of the long time required before obtaining the first heat of the day and the expense of handling the coal and ashes.

Reply 145, subdivision 27.—[Reply to question "Give cubic feet of gas used per furnace per day" was "100,000 cubic feet."

Reply to question "Give total pounds of metal charged per furnace per day" was "687 pounds." These answers indicate that about 14,500 cubic feet of gas per hundredweight of metal was used—a manifest error. A letter of inquiry on this point brought no reply.]

Reply 146, subdivision 18.—The amount of fuel used by brass manufacturers averages about 2½ gallons to 180 pounds of metal. [This is equivalent to about 1.4 gallons per hundredweight. No definite statement was made that the oil consumption at this particular plant is as low as that.]

We have found the oil furnaces the cheapest; with crude oil at 4 cents per gallon, delivered, we have an advantage of 30 to 33 per cent over coke.

Reply 149, subdivision 9.—Our total output is 2 tons per week; we use 2 tons of hard coal per week. [It is not certain whether the output refers to metal melted or to castings produced minus gates and sprues.]

Figures are based on both yellow and red brass.

Reply 150, subdivision 17.—We prefer crucible furnaces for small operations.

Reply 151, subdivision 10.—[See notes on Reply 17 relative to rolling-mill furnace tenders.]

We use a salt flux and skim into water, the charcoal and dross recovered being put back on other crucibles later, until the slag is too thick. We recover twice as much metal from the skimmings as from the ashes.

Reply 152, subdivisions 13, 30.—The difference between the weight of metal charged and [trimmed] castings delivered is 2.79 per cent. The net loss for 1912, crediting recovery from slag, grindings, spillings, and skimmings, was 1.86 per cent. This figure covers all foundry losses, grinding losses, etc., as well as the actual melting loss. The actual melting loss, or difference between metal charged and poured, is 0.51 per cent. [This figure seems to be based on complete foundry records.]

We have used ordinary pit furnaces and two makes of tilting coke furnaces and tilting oil furnaces. Each form of tilting, coke or oil furnace has been supplied with forced draft. Relative economy depends upon market values of fuel. Have noted no material difference in loss of metal during melting between oil and coke furnaces now in use with bronze mixtures, nor does there seem to be a difference in final analysis of the metal or of the castings in the testing machine.

The air supply for both coke and oil furnaces is preheated.

The oil consumption runs from over 2½ gallons per hundredweight on the first heat, which takes a little over three hours, to 1½ gallons per hundredweight on the last, which takes a little less than two hours.

Reply 154, subdivision 14.—It has been our experience that the pit furnace is an ideal furnace, but we have noticed considerable economy in using the forced-draft, tilting, coke furnace, such as we are using, as it gets heats out much more quickly and gives better metal than does the pit furnace.

[The reply to the question as to pounds metal per furnace per day was "2,000 pounds;" as to pounds of fuel per furnace per day the reply was "150 pounds of hard coke," or 7.5 pounds per hundredweight. A letter asking for verification of this low figure was unanswered.]

Reply 155, subdivision 7.—After the first three months the furnaces are repaired about once a month. They are relined every six to eight months.

Reply 156, subdivision 32.—We have no positive figures for amount of fuel used a day under present operating conditions, but previous tests show that this will run from 3 to 4½ gallons of oil per hundredweight of metal melted, assuming the metal to be "gun bronze."

We usually run two heats per furnace per day, although many more heats could be run if a larger amount of metal was wanted per furnace. We find it takes 30 minutes to 1 hour for preheating the furnace and 30 to 45 minutes to melt the charge.

Furnaces are relined about once a year, and slight repairs are made by us daily by use of fire clay and carborundum.

As to relative advantages and disadvantages of different types of furnaces, we have found that for melting the high-copper bronzes and low-zinc bronzes the best results are obtained by the open-flame oil furnace, where the entire heat is melted in one furnace rather than being distributed among a number of crucibles. If care is taken to have the furnace well preheated and to run a flame without excess of air—that is, a smoky or reducing flame—and if the metal is poured when it is ready and not held in the furnace too long after it has reached the proper temperature, good results can be obtained with these furnaces. We have obtained a tensile strength as high as 52,500 pounds and an elongation of 50 per cent in a number of cases with the regular Government "gun bronze," 88 per cent copper, 10 per cent tin, and 2 per cent zinc, and have done work for outside parties in this type of furnace when they had failed to meet Government requirements in their own foundries where they employed crucible furnaces. When metals containing a large percentage of lead and zinc are to be used, there is probably an advantage in the use of crucible furnaces on account of the high percentage of volatilization that would occur in a direct-flame furnace with these metals of low melting point. For high-heat bronzes we have found no trouble whatsoever from this source.

We are pleased to note that you are going to study this problem, as we have conducted a number of experiments in our own plant to determine the proper melting conditions for the metals that we are usually using, and we have found that practically all of the troubles we had been experiencing could be solved by a proper determination of the pouring and melting temperatures, the length of time that the metal is heated, and the proper control of the air and oil pressure at the furnace.

Reply 157, subdivision 16.—We use a No. 70 crucible, getting six heats in 10 hours, five furnaces per tender; metal 85 per cent copper, 5 per cent zinc, 5 per cent tin, 5 per cent lead; and 60 per cent copper, 35 per cent zinc, and 5 per cent lead. We use 20 gallons of oil per furnace per day. The amount of metal charged varies and we keep no record. [If the usual charge of 200 pounds per No. 70 crucible were used, the data given above would indicate the quantity of metal charged to be 1,200 pounds per furnace per day, or an oil consumption of about 1.7 gallons per hundredweight. These data are not included in the tabulation because of the uncertainty as to the quantity of metal melted.]

We have used coal and oil; oil is better as regards the output. The shrinkage is a little higher, but the quality of the metal is about the same. Oil is at least twice as fast.

Reply 158, subdivision 7.—We use a No. 60 pot. We have tried a No. 100, but the metal cools too much before we can pour it all into our light work. There is a good deal of unburned coal in our ashes; the coal is riddled out and used for melting aluminum.

Reply 160, subdivision 20.—We patch burnt-out places on the furnace every day.

Reply 162, subdivision 1.—The foundry is small, having only three pits and at the present time two molders; one tender takes care of the furnaces and helps the molders to pour off and does general work in the foundry.

If we use a special brand of fire brick much used for blast-furnace linings, the lining lasts 10 to 12 months. If, however, we use an inferior fire brick, such as is used for ordinary blacksmith forges, the furnace would have to be relined every 5 or 6 months.

Our patterns are all small, sometimes as many as 12 patterns being gated together, and the gates ofttimes weigh more than the castings.

The average loss during melting is 3 per cent.

Our foundry is thoroughly swept every week; even the shelves for patterns, etc., are all thoroughly swept. One of our molders has been in our employ for 30 years and the other for 25 years. There are no rules given to them.

Reply 163, subdivision 1.—I have had experience with all styles of furnaces. We are not using any furnaces aside from the crucible coke furnace at the present time, as I consider this the best and most economical furnace for melting nonferrous metals.

The crucible used is standard size No. 100 special crucible, holding 340 pounds of metal. Amount of fuel used per furnace per day, 400 pounds of 72-hour foundry coke. Furnaces are relined about every four months, but flues are repaired about every four weeks; 2,040 pounds of metal charged per day per furnace.

The reason we obtain such a low melting ratio of coke to metal is due to the fact that most of the alloys used at this foundry have a rather low melting point, and furthermore the hot crucible is immediately placed into the furnaces again, and in the bottom of the crucibles there is a bath of 25 or 30 pounds of metal, and, as you know, this arrangement greatly facilitates the melting of additional metals placed in the crucible. This ratio of coke to metal melted has been checked and is correct.

Reply 164, subdivision 26.—The average time of heat after the first heat in the morning is 1 hour and 20 minutes, the first heat taking 2 to 2½ hours.

This plant consists at present of 16 furnaces and is being handled by two men, so that one man can take care of eight furnaces. This is one man less than was formerly used with oil furnaces of the same capacity.

As to the number of heats per crucible, at the present time they average only about 20. However, experiments have been made that prove conclusively that with a little additional equipment this life may be brought to 30 or 35 heats. The experiments have been thorough and in a very short time will be applied commercially at this plant.

I can not state definitely how often the furnaces have to be relined. The practice at this plant is to make one man responsible for the condition of the furnaces, and they are gone over every Sunday and when the lining shows any wear it is patched with a mixture of silica fire brick. I do not believe that the actual lining of the shell is changed more than once in three months.

The gas used per hundredweight of metal averages about 3,500 cubic feet after it has attained a working temperature, or about 7,000 cubic feet per pot of metal. This quantity is dependent upon the composition of the metal used and the temperature to which the metal is brought before being poured. The temperature in the preheater is about 600° F.

The gas, when Pocohontas coal is used in the producer, yields about 120 British thermal units per cubic foot and contains about 8 per cent of carbon dioxide, 18 per cent of carbon monoxide, 3 per cent of methane, 13 per cent of hydrogen, and about 58 per cent of nitrogen.

The metal loss on test conducted recently, averaged from 0.75 to 1 per cent. This is considerably less than previously lost with oil, but is probably the result of being able to obtain a more practical mixture of gas and air on a gas furnace than it is possible to obtain with oil and air on an oil furnace, so that the furnaces can be operated with a reducing flame.

In considering the above it is well to note that these results mean more when one takes into consideration the class of the product. The product of this company consists of numerous very small castings. In some cases the metal is not much more than one-sixteenth to three thirty-seconds of an inch thick, and the gates of a flask represent as high as 85 per cent of the entire weight of metal. It is the practice for one man to set up 10 to 12 flasks at a time, before pouring. On account of the very small castings the metal must be very fluid and have a very high temperature when it leaves the furnaces, so that it will have required the fluidity for the last flask. It is

rather an unusual practice and it will no doubt be interesting to know that the temperature of the metal, as it leaves the furnaces, is from 2,200° to 2,300°, the temperature of the furnaces operating being only about 2,500° to 2,600°. I might also add that the spelter and tin are added to the charge after it has been drawn from the furnaces.

Reply 165, subdivision 9.—Very strong draft. Prefer natural-draft furnaces, as in them metal is more thoroughly mixed and has closer grain, and there is less shrinkage.

Reply 166, subdivision 7.—There is very little difference between the quality of the metal from various types of furnaces. [This reply was received without address.]

Reply 167, subdivision 27.—Furnaces constantly repaired. [This reply was received without address.]

Reply 168, subdivision 1.—[This reply was received without address, and so that no further inquiry could be made. The quantity of fuel per furnace is given as 350 pounds, and the metal melted per day per furnace as 150 pounds, figures that would represent a fuel consumption of 233 pounds of coal per hundredweight of metal, a ratio that is improbable. As the number of furnaces one furnace tender handles is given as four, which is below the normal for this size, it is probable that this foundry has four furnaces of this size and that the fuel consumption is given on the basis of all of them, or a coal consumption of 58 pounds per hundredweight, a more likely figure.]

Reply 169, subdivision 32.—The open-flame furnace gives just as good metal as any other. We have used it for 10 years on the highest grade of valve work, with complete success. We use pit coal-fired furnaces very rarely in cases where we must get a zinc analysis exact to formula. We would not use the open-flame furnace if it did not give the highest possible quality of metal for our purposes, as with us quality is paramount.

Reply 170 subdivision 13.—In the open-flame oil furnace the loss of metal due to oxidization is large, and poor metal for pressure work is produced. The pit furnace in which the crucible is removed and the molds directly poured is best for pressure work. Fifty-eight heats for the life of our crucibles is a low figure. We are using foreign crucibles, however, not domestic.

[The makers of this furnace state that the firm supplying Reply 170 at one time gave the furnace tenders a bonus of 10 cents per heat for each heat over 50 that they could get from a crucible. At that time they were averaging 68 heats per crucible on a 10-hour working day. Rush of business made it necessary to run 24 hours a day for a short period. During this time the average life of six crucibles, run continually, was 110 heats per crucible.]

Reply 171, subdivision 7.—We could make three heats a day. Furnaces are repaired every 25 heats.

Reply 172, subdivision 7.—We have tried both natural and forced draft on several sizes of our furnaces. The results of some tests follow:

Results of fuel tests with various sizes of crucibles.

Crucible No.[a]	Capacity.	Fuel per hundredweight with natural draft.	Fuel per hundredweight with forced draft.
	Pounds.	*Pounds.*	*Pounds.*
70	225	31.2; 28.5	34.5
80	285	[b] 30	38.6
90	325	23.7	....
90	295	....	2C
95[c]	300	23 to 28	....
100	280	31.4	....

[a] All crucibles were special except No. 100. [b] Average. [c] A thin-walled crucible.

On the No. 90 we could get four heats per day on forced draft, whereas we could get only three on natural draft.

The "pinch" type of tongs is used.

Reply 173, subdivisions 31, 37, 40.—We use a tilting, open-flame, oil furnace holding 2,500 pounds, a stationary rectangular oil-fired reverberatory furnace, holding 4,000 pounds, and two bituminous-coal reverberatories of the same general form as an ordinary reverberatory copper furnace, holding 7,000 pounds each, with oval hearths 6 by 8 feet. We have no data on the oil consumption in the oil furnaces as they are not metered separately from the annealing furnaces. Records for six months show a coal consumption of 50½ pounds per hundredweight of metal melted in the large reverberatories. The gross melting losses are 2 per cent in both types of oil furnaces, and 5 per cent in the reverberatory coal furnace.

There is a large recovery from the heavy slag formed in the coal furnaces, which will bring the net loss figures from all types close together.

We pour all metal as cold as possible. Our ingots or cakes are large and heavy. We have no trouble in pouring them from any of the three different types of furnaces in use.

With oil at a reasonable price, we prefer the tilting, open-flame, oil furnace, and if we were fitting out anew, we would use these entirely. A series of analyses of the product for a long period shows maximum variations of about 1 per cent of zinc each side of the analysis aimed for, the average variation being very small. With the coal-fired furnace there is no trouble from the metal taking up sulphur.

Reply 174, subdivision 32.—One furnace tender handles one furnace, which includes weighing, charging, mixing, and repairing the lining and ladles, melting on an average 5,700 pounds per day of nine hours. We repair the lining each day. Our loss is 1½ to 2 per cent on new metal, and 2 to 5 per cent on scrap metal. I have never observed any difference from a physical standpoint with the furnaces we have used.

Reply 175, subdivision 32.—We find no difference in the quality of metal from the different furnaces we have tried.

The spherical furnace is lined with fire brick 8 inches thick; the egg-shaped one is lined with carborundum fire sand 5 inches thick.

One furnace tender and two helpers handle our four furnaces. Their duties include trucking, weighing, charging, distributing, and pouring of metal; also the repairing of the lining and ladles. We melt 15,000 pounds per day of nine hours.

On test, we have melted 100 pounds of metal with 2 gallons of fuel oil.

From tests we have run, we found a loss of 1½ to 2 per cent in new metal, and from 2 to 5 per cent in scrap.

Reply 176, subdivision 30.—We have used only one kind of oil furnace. Do not know correct comparison. Oil furnace is cheaper than coke furnace, as coke here in the West is more expensive than Eastern coke, and oil here costs very little as compared to coke; quality of metal seems to be about the same.

Reply 177, subdivision 1.—Coke is the only fuel we have used. We are converting one furnace so that natural gas may be used in tests. The cleanliness and rapid melting of gas furnaces we think will be advantageous; also less labor will be required.

Reply 178, subdivision 24.—[Furnace is probably of the 3-burner type. This reply was noted on the question sheets and received without address; hence no inquiries could be made for further details or to verify the figure for gross loss.]

Reply 179, subdivisions 28, 32.—We find advantages in using tilting, oil-fired, crucible furnaces as against the open-flame furnaces, as the melting loss is lower and the metal is more homogeneous.

Reply 180, subdivisions 14, 40.—In the forced-draft, tilting, coke furnace we use English crucibles. In these we have to coke up every 15 minutes, which makes it hard on the melter. The coal-fired reverberatory has a melting chamber about 6 by 8 inches and can be used for a charge of 1 to 15 tons, according to the amount of sand

put on the melting floor. A 5-ton charge is normal. With a cold furnace we get a 5-ton heat out in four hours on ingot or scrap manganese bronze. For new metal it takes 5 hours. On a 5-ton charge the furnace requires one furnace tender throughout the heat, and two other men about one and one-half hours to charge it. The bridge lasts 15 heats, the walls 30.

The gross melting loss on manganese bronze is 3 to 4 per cent. With 20 per cent of chips, the gross loss is 5 per cent. On gun metal it is 2 per cent and the net loss 1 per cent. We do not find any trouble from the taking up of sulphur during melting, either with manganese bronze or gun metal. We use 800 pounds of coal for a 5-ton heat.

There is no difference in the quality of the metal produced by either of these types of furnace or the natural-draft pit furnace.

Reply 181, subdivisions 9, 18.—Our crucibles have an outside diameter of 11¼ inches at the bilge. We are just trying out a pit, oil furnace, using low-pressure air, with encouraging results.

[There was a great deal of unburned coal in the ashes from the coal fires at this plant.]

Reply 183, subdivision 1.—We are using the round-pit type of furnace made by us; 36 inches high from the grate bars, with various diameters to suit No. 40, 60, 80, and 100 crucibles. We use a lining of fire brick and special clay, having a total thickness of 4 inches. The cover is oval, 22 inches in diameter, and is made from manganese steel.

We reline our furnaces about every 4 months, also make slight application of special clay every 2 or 3 weeks. Our crucibles average 31½ heats.

The undersigned has had experience with almost every kind of furnace except electric and has obtained best results in this locality [far West] with the use of Washington coke; in the Middle Western States, Lehigh Valley hard coal gave best results.

Reply 184, subdivision 1.—Have used the oil furnaces where brass or metal is in fuel chamber, and no crucible used, and I find it very hard to detect when the metal is at the proper temperature at which to pour or tap it from furnace. It is either not fluid enough to make a homogeneous casting, or it is burned. Also it absorbs too much oxygen, making castings porous and brittle. The loss in melting will in most cases exceed 6 per cent.

By using the crucible oil burner I find no appreciable difference in metal made from a coke pit furnace, except the advantage of rapid melting in the oil furnace using crude oil.

Reply 185, subdivisions 11, 32.—The oil furnace is of the open-flame type, rectangular, about 4 feet 6 inches long by 3 feet 6 inches wide by 3 feet high, outside dimensions. There is a charging door about 2 feet square on the front; directly below this is the pouring spout. The furnace is mounted on trunnions and tilted by a handwheel and worm gear. The burner is set in the top of the furnace and points directly down to the melting chamber. [The inside dimensions and shape of the melting chamber were not given.]

The loss figures [in subdivision 32 of the table] are on 125,000 pounds of metal melted in the oil furnace. On 75,000 pounds of metal melted in the oil furnace, which contained 85½ per cent copper and 18½ per cent tin [rest probably zinc], the gross loss was 6.3 per cent and the net loss 4.9 per cent. On 50,000 pounds of an alloy consisting of 90 per cent copper, 7 per cent tin, and 3 per cent lead, of which three-fourths was melted in the oil furnace and one-fourth in the coal furnace, the gross loss was 2.3 per cent and the net loss 1.1 per cent. The net loss is figured as the gross loss less the metal recovered from the slag. The gross loss includes grinding losses, spillings, etc., but no correction is made for this in the net figure.

Reply 186, subdivisions 1, 16.—We use coke melting furnaces and also pit, oil furnaces, but will shortly discontinue the use of the latter on account of the increased cost of fuel oil. The coke furnaces average 4 heats per day. The oil furnaces average

6 heats per day, although we have obtained as many as 8 heats per day. The results mentioned are based on a 9-hour day. There is no specified time for relining furnaces, we having found it best to keep up a sort of constant weekly repair.

The average good crucible gives us about 22 heats, but this is an average of 5 heats less than we formerly obtained.

The number of gallons of oil used has greatly varied, but an average for about 12 months is 4.665 gallons per heat, and a 10-month average of coke used indicates a consumption of 69 pounds per heat.

At the present time the gas company in the city is preparing two of our furnaces for trial purposes, claiming that it is able to get 9 heats a day, and that it has melted material at a cost of 5 cents per hundredweight. This is by the use of natural gas at a price of 30 cents per 1,000 cubic feet.

Reply 187, subdivisions 28, 32.—We use two double-chamber, open-flame, oil, tilting furnaces, without crucibles, and one crucible, tilting, oil furnace.

The double-chamber furnaces are oval, the smaller being about 20½ by 48 inches, with a melting capacity of 700 pounds for each chamber. The larger are 26 by 63½ inches, with a melting capacity of 1,500 pounds for each chamber. The crucible furnace takes a 275-pound crucible and has a melting capacity of nearly 800 pounds.

The lining material for the double-chamber furnaces is a mixture consisting of 57 per cent silica sand, 29 per cent Duncan clay, and 14 per cent ground graphite crucible material, thoroughly mixed and wet with water to the right consistency, to which is added one-half pint of silicate of soda to every 2 gallons of water. This lining is about 5½ inches thick when the furnaces are newly lined. The crucible furnace is lined at present with a special fire brick which came with the furnace, but we expect to make all relinings of the same material as we use in the double-chamber furnaces. The fire-brick lining is about 9 inches thick.

We do not use the waste gases from any of our double-chamber furnaces to heat the other chamber not in use and have the passageway between the two entirely closed; in consequence we have removed the doors from over the charging holes on these furnaces. The charging holes on the larger of these furnaces are 12 inches in diameter and on the smaller 10½ inches. We have a much greater melting capacity than would meet the demands for castings made in our brass foundry, but we make a great many copper castings, the life of which depends on our being able to make them over 99.40 per cent copper. Likewise we make quantities of high-grade babbitt metals, and have found from experience that the only way we can keep and make these materials free from alloys not intended to be found in them is to keep certain furnaces for certain classified castings; hence the closing of the passageways between the double-chamber furnaces and the removal of the charging doors for escape of gases.

The specific gravity of the oil used is 0.865 (31.85° B.); pounds per gallon, 7.21; British thermal units per pound, 19,316; British thermal units per gallon, 139,268. All calculations based on a temperature of 60° F. A 40-pound pressure is used on oil at burner and 11 to 13 ounces on air at burner. A special needle-valve burner of our own make is used. The discharge orifice of this burner is made by a No. 56 drill; a No. 60 drill mounted on the end of an adjustable stem protrudes through the orifice. The oil as it passes through the discharge orifice of the burner is compelled to pass through and follow the corrugations of the drill, giving it a whirling motion, and the spray, being very fine, easily gasifies, and we get a flame that completely fills the volume of the furnace and insures perfect combustion. We claim that our loss in melting and comparative freedom from oxidation is due largely to this type of burner. The burner that came with the furnaces when first installed discharged a straight stream, three-sixteenth inch thick, directly on the metal, and it was a task to take off a heat without burning the metal.

Our furnaces are not metered, and it is therefore impossible to tell the exact oil consumption. We use oil for drying purposes in two ingot mold ovens and two core

ovens which are metered. At the end of the month all oil used in excess of that shown by the meters on these ovens is charged against our brass-foundry operations. We did, however, once make a test of a single chamber of one furnace on copper castings. We melted nearly 7,400 pounds of copper in seven heats with 105 gallons of oil. Our brass-foundry core oven and one other small oven were also running a part of the time during this day, and we have no means of telling just what amount of oil was consumed by these ovens. Thus it took less than 1.4 gallons per hundredweight of copper.

Ten hours constitutes the working day in our foundry, but the average time of running the furnaces, from starting the fires to taking out the last heat, would probably not exceed seven to eight hours on any single day.

Furnaces are not relined oftener than once in five months. Small repairs around charging hole are made every two or three days.

The average life of a crucible does not exceed 13 heats in our crucible furnace.

Our heats vary greatly. This is really a jobbing foundry and there are no two days alike. Neither our room nor our requirements would permit us to wait until we got enough molds made up to equal the capacity of the furnace before casting. We make many small heats from our furnaces, by reason of special metal mixtures being required. In copper castings it is imperative that all new metals be used. In large bearings, where work is extra heavy, we use a mixture consisting of 79 per cent copper, 10 per cent lead, 10 per cent tin, and 1 per cent phosphorus. We can use from 20 to 40 per cent of scrap in these, provided we have scrap of which we know the alloy content; otherwise all new metal is used. We have other castings in which 70 per cent is used. We do not use very many borings.

The average net losses in melting are: For copper castings, 0.85 per cent; brass, 1.6 per cent; and yellow brass, 2.25 per cent. Would recommend coke crucible furnaces where large quantities of yellow brass castings are required. We make very few castings of this metal.

We are very partial to the double-chamber, tilting furnace, without crucible, as used in connection with our own type of burner. Its speed in melting, its accessibility, and the low cost of making repairs all appeal to us as being superior to the coke-fired furnace. We can not see where castings made from the crucible furnace are in any way better than those made from the chamber furnaces. The cost of the crucible and the slow melting of the metal in the crucible, it seems to us, militate against its use. The present cost of crude oil is about the worst feature of an oil-fired furnace, but even in this respect we are confident that the oil-fired furnace, of the chamber type, will not consume within 80 per cent of the fuel for melting that the oil-fired crucible furnace will consume. Our physical test for oxidation in copper consists in bending or doubling a five-eighths inch square, cast-copper, bar casting about 6 inches long, while heated to a cherry red. If there is any amount of oxidation in the piece, it will break on bending. We usually have very little trouble in making this test.

The waste heat from our melting furnaces is sometimes used to heat a large piece of scrap brass, too large to be charged into the furnace. These pieces are laid on the top of the furnace, over the charging hole, until they become hot enough to break. This is the only use we can make of this waste heat. All skimmings, spills, and furnace droppings are put through our water tumbling mill, thoroughly washed and cleaned, and thrown back into the furnaces. This is a daily routine.

Reply 188, subdivisions 1, 16, 32.—On the coal and coke furnaces we use a coal bed and a coke filling, one-third coal and two-thirds coke being used. Crucibles average 15 heats in pit; oil furnace, 10 inches in coal and coke. We melt red brass, gun metal, phosphor bronze, and yellow brass.

Our average gross loss on all the alloys we melt, taking all furnaces into consideration, is 3½ per cent, including slags, skimmings, etc.

Reply 189, subdivisions 10, 18, 29, 33.—[See notes on Reply 17 as to rolling-mill furnace tenders.]

We use square, pit, coal-fired furnaces in our rolling-mill melting, and oil furnaces, pit, crucible tilting, and open-flame reverberatory furnaces in running down borings and light scrap into ingot. In the 16-inch square (inside) fire we use a pot holding 240 pounds, having an outside diameter at the bilge of 13¼ inches; in the 18-inch fire, one holding 450 pounds and with a bilge diameter of 15¾ inches. We have 10 furnaces on a stack. The draft is so strong that we usually reduce the size of the flues in each furnace by laying a brick in them. Our egg coal has 12 to 14 per cent ash, runs about 13,000 British thermal units, and has 0.5 to 0.7 per cent sulphur. We have found SO_2 and CO in cavities in copper and gun metal, but no sulphide S. There is no trouble from S or SO_2 in yellow brass. The coal furnaces are relined every 900 heats, no patching being done in the meantime. It would probably pay to patch. The gross loss on 2 to 1 yellow brass is 1.75 per cent and the net loss 1.25 per cent. The net loss on pure copper is 0.5 per cent.

In the refining plant we use tilting, oil furnaces, with crucible, which we do not like as well as the pit oil furnaces. We also use a tilting, open-flame, reverberatory furnace about 6 feet long by 4 feet wide by 3 feet 6 inches high, outside dimensions, with a pouring spout at one end, a burner entering horizontally just above it, and a charging door at the top. It is much like an ordinary oil reverberatory furnace, only made tilting by mounting on trunnions. This is rated at 500 pounds capacity; we usually charge 600 and can get 1,200 pounds in it. One man can handle two of these with aid in charging.

The lining of this is in good shape, after 900 heats, running steadily. We do not have our oil furnaces metered and can not tell the oil consumption. The gross melting loss in the crucible, pit, oil furnaces, based on oil-free borings, is 5 per cent, in the tilting-crucible furnaces 5.5 per cent (the higher figure being due to the double pouring into and from a ladle, necessary when a tilting furnace is used) and 10 to 12 per cent on the open-flame reverberatory. Notwithstanding this, the open-flame reverberatory furnace has such advantage in the matter of speed that we shall in time discard the crucible furnaces. We consider this type of open-flame tilting furnace better than the more common types.

We pour as cold as possible in the refining department, but very hot in the rolling-mill casting shop, the metal practically boiling. As the mill losses in rolling due to defective castings were so high when trying to pour ingots at a low temperature for rolling purposes, in order to reduce zinc losses, the cost from that cause far overbalanced the saving of zinc.

After the crucibles from the tilting furnaces have become useless through the breaking away of the edge, we cut off the top and get a few more heats from them in the pit furnaces.

There would be no difficulty in arranging matters so as to pour directly from the lip of the tilting reverberatory, or a similar furnace, into the molds in the casting shop of the rolling mill on most castings weighing over 50 pounds, and it could certainly be done on a very large proportion of the work. But the zinc loss in this type is too great to make this practical with oil or gas fired furnaces.

Reply 190, subdivision 30.—Furnaces are repaired weekly.

We believe that our oil consumption amounted to about 3,000 gallons to every 50,000 pounds of metal melted. We don't know the relative oil consumption of the large and small furnaces. We could get as many heats from the big furnace as the little ones. The life of the crucible was just the same in the small as in the large furnace.

We believe the oil furnace has a tendency to burn the metal. The principal disadvantage, besides the difficulty in buying oil at a fair price and the procuring of

proper labor, is the uncertain results owing to the amount of loss from apparently no cause whatever.

[The air pressure was given as 10 pounds and the oil pressure as 80 pounds, but the make of burner used is said by the maker to be designed for an air pressure of 4 to 6 ounces and an oil pressure of 40 pounds. In response to an inquiry on this point, it was stated that the figures given were correct. The high oil consumption and the tendency to burn the metal may thus be due to operating the burner under conditions for which it was not designed.]

Reply 191, subdivision 32.—Our test showed an average of 1 gallon of oil used to 49 pounds of metal charged into furnace. Oil was metered by a ¾-inch piston meter. During our test of three days we ran four heats per day, although we often run five heats from a furnace. Actual time from lighting of furnace until shut-off of blast on last heat was 7½ hours. We have to reline these furnaces three times a year, and ordinarily do a little patching each week to keep them in perfect working condition.

Some of our pouring crucibles (No. 35), used as ladles, last only three or four days, on account of breakage, whereas others last much longer; however, we believe that about 450 pots of metal is the average active life of a crucible; we use them for pouring only.

We know of no positive difference in physical tests, pressure tests, or behavior in the foundry between the metal from our present furnaces and from the old coke furnaces.

Reply 192, subdivisions 10, 33.—[Reply 192 was not sent by the firm whose practice it represents, but the data were given by another firm to which they had been given by a representative of the first firm. These figures show the net loss on 2-to-1 yellow brass for different casters as 1.44 per cent, 1.55 per cent, and 1.60 per cent; the net loss on yellow brass, including one-fourth of an alloy consisting of 90 per cent of copper and 10 per cent of zinc, as 1.30 per cent; on pure copper and some 90-to-10 brass, 0.59 per cent. Thirty pounds of coal and coke per hundredweight is used for yellow brass, and 36 pounds on 90-to-10 brass and copper. The crucibles last 35 heats on yellow brass and 8 heats on copper. The gross loss on yellow brass is about 3 per cent, 1 to 1.5 per cent being recovered from the ashes and skimmings.

An open-flame, oil furnace is also used on 2-to-1 yellow brass, and the net loss in this is 3.4 per cent. It is said that there are two distinct opinions in this plant as to the over-all economy of the open-flame furnace. It is reported that the chemical staff is against and the practical millmen favor its operation. Still later reports indicate that the use of the open-flame furnaces at the plant has been entirely abandoned.]

Reply 193, subdivision 9.—We have tried producer gas in a large unit, but found it unsuccessful owing to oxidation.

Reply 194, subdivision 10.—As to the fuel consumption, with No. 65 and with No. 70 crucibles, as near as we can estimate, this is practically the same. Of course we get more metal from the No. 70, but it takes a trifle longer to melt and perhaps a little more coal. We have never figured the matter out as fine as this.

As to the life of crucibles, our average for the year 1912 was 58.98 heats per crucible. We think you will find this average considerably higher than any other average you will get, as we understand from the crucible makers we get a longer run than anyone else, evidently due to the method of handling.

As to the size of our No. 65 crucible, it is 10⅞ inches at the top, 11⅝ inches bulge, 7½-inch bottom, and 15 inches high. The size of the fire at the bilge of the crucible is practically 14 inches square.

The furnace is built somewhat larger at the top and tapered at the bottom, but of course after a few months' use in punching the fires, the bottom gets considerably larger.

Regarding handling of crucibles, we have had a good deal of experience with the handling, and have found out that by careful use and preparation the life of crucibles can be considerably prolonged. The details of this we do not care to give out.

As to the building of tongs, they have considerable to do with this also, and think we had rather not discuss the matter.

[Admission was not granted to this plant.]

Reply 195, subdivision 3.—Oil furnaces burned the metal.

[This reply was noted on the question sheets, without address, so that no inquiry could be made as to the astonishingly low figures for melting losses, which are probably incorrect.]

Reply 196, subdivision 32.—We make a very light class of brass castings, containing 10 per cent of zinc, a casting often weighing only a fraction of an ounce. We are able to get our 10 per cent zinc metal hot enough to run such castings, poured from a ladle, with the open-flame oil furnace, with an average gross melting loss of 4½ per cent, using about one-fourth borings or very light scrap and three-fourths gates or ingots. We do this by maintaining a strongly reducing flame and by getting the heats out just as quickly as possible.

We melt a red brass which is lower in zinc content for these light castings in a very small crucible in pit fires, because we can not get this higher melting alloy hot enough to be transferred to a ladle without getting too cold to be poured before the ladle is empty. We prefer the open-flame oil furnace to any other for our light work with the 10 per cent zinc alloy.

Reply 197, subdivision 1.—We have and use occasionally two crucible oil furnaces which are very satisfactory, except the cost of fuel oil in New York City.

Reply 198, subdivision 23.—The furnace is rectangular, 10 feet 6 inches long, 5 feet 5 inches wide, 4 feet 9 inches high, with 3 chambers 28 inches long, 18 inches wide, and 33½ inches high. Lining of fire brick, 9 inches thick. Cover is rectangular, 36 by 24 by 4 inches. Framework of structural steel, covered with fire-brick slabs. Nos. 100, 60, and 40 crucibles are used. No burner is used, as the pan system is employed with a natural draft obtained from an 80-foot stack. Approximately 1 gallon of fuel oil is used per hundredweight of metal. The furnace is relined about every 15 months, slight patching being done every 2 weeks. Average life of crucible is 15 heats. Gross loss during melting 2.1 per cent; 2.05 per cent net is the loss during melting, taking account of all metal recovered.

Reply 199, subdivision 8.—Both round and square furnaces are used; figures for both lumped together.

Reply 200, subdivision 10.—[See notes on Reply 17 regarding furnace tenders.]

The figures on coal and coke (62½ pounds) are based on 100 pounds of metal. This may seem high, but it combines the brass and German silver, the latter comprising most of our melt.

Reply 201, subdivisions 2, 24.—The figures for gross losses in melting on both the coke and the gas furnaces are on one week's run of turnings. Other figures are averages for regular practice.

Our experience has shown that the gas furnaces have the following advantages over the coke furnaces: (1) Reduction of melting cost, owing to: (*a*) Cheap gas fuel in this district; (*b*) rapidity of melting; (*c*) longer life of lining; (*d*) elimination of coke and ash handling and storage; (*e*) ease of recovery of metal from broken and leaking crucibles; (*f*) small volatilization loss due to shorter melting time; (2) increased efficiency of tenders, owing to less exposure to the heat because of absence of coking and poking.

The advantage of the coke furnace is the longer life of crucibles and the absolute reliability of fuel supply, although this last item has not been of importance, as our gas supply has been uninterrupted for a period of two years. The physical properties of the metal are identical in both methods of melting.

The "pinch" type of tongs is used.

Reply 202, subdivision 39.—The furnace is a reverberatory furnace, similar to a malleable-iron melting furnace, except that the metal hearth is shorter and deeper. The furnace is rectangular, 18 feet long, 5 feet wide, and 6 feet high, outside dimensions. The coal and combustion chamber is 5 feet from end of furnace to bridge wall, inside measurements, but the inside width of furnace is 3½ feet.

The metal chamber is 9 feet long by 3½ feet wide, inside. Beyond the metal chamber is another chamber 3 by 3½ feet, inside, which leads to stack. The tap hole is 2 feet above the floor. Furnace is fired with melting coal, mechanical stoker, with top and bottom blast, being used.

Lining: Sides, 9-inch fire brick; bottom, silica sand, 18 inches deep in lowest part. Cover: Fire-brick bungs, 5 feet by 18 inches wide. The fuel used is Pennsylvania or West Virginia melting coal—same coal as we use in our malleable furnaces. Average analysis of coal: Moisture, 1 per cent; volatile matter, 34 per cent; sulphur, 0.7 per cent; fixed carbon, 59 per cent; ash, 6 per cent; 13,500 to 15,000 B. t. u.; pressure at fan, 11½ ounces.

When running two heats a day, which we generally run, one man tends the furnace. His duties are to charge the metal into the furnace, fix furnace up for next heat, wheel up coal, take out ashes, break up and pick metal from slag, take castings over to the tumbling barrels, clean up floor, etc.

Usually two heats per day are made, except Saturdays, when we run one heat per day, working only till noon. When crowded, we run three heats per day. When we run so slack that 300 pounds of metal or less is required, only one heat is taken off. The working hours of the furnace are 10 hours a day of two heats; it is relined about once every two years.

The net percentage of loss during melting, taking account of metal recovered from all metal-bearing refuse, was, 1909, 2.55 per cent; 1910, 1.57 per cent; 1911, 2.58 per cent; 1912, 2.93 per cent. The melting-loss and fuel-consumption figures are based on records for 3,000,000 pounds of red brass.

The chief advantage of this furnace is low cost of melting and operation. We do not think that the metal from this furnace is quite as clean as from crucible furnaces, and would not use this furnace if we were making a very high-grade bearing bronze. However, we get a good grade of metal, and the castings machine up very clean. We have no record of physical or pressure tests.

Pouring takes about 20 minutes to one-half hour for every heat.

Reply 203, subdivision 1.—[See notes on Reply 17 relative to rolling-mill furnace tenders.]

The crucibles we use have the following dimensions: Outside diameter of top, 10¾ inches; inside diameter of top, 8¾ inches; outside diameter of bilge, 12 inches; height over all, 16½ inches; height inside, 14¾ inches; capacity, about 200 pounds of metal.

The fuel we use is a good, medium-hard porous, 48-hour coke, burned under natural-draft stack.

One furnace tender can handle 10 furnaces. He is assisted by three helpers, a pot puller, mold ringer, and mold cleaner.

Furnaces are relined about once in four months, and minor repairs are made as required.

The average yearly melting loss is 1.68 per cent gross.

Average analysis of German silver: Copper, 62 per cent; nickel, 15 per cent; zinc, 23 per cent.

Average analysis of phosphor bronze: Copper, 95 per cent; tin, 5 per cent.

We make no brass.

For foundry work nearly every type of furnace can be made to yield good results, whether reverberatory, tilting, with or without crucible, or pit furnaces using crucibles; but for ingots required for rolling there is no doubt in my mind of the superiority of

melting in crucibles with natural draft, taking precautions to preserve the metal from the action of the air as completely as possible.

We consider coke far better than coal for our work. Coal would be too slow.

Open-flame oil furnaces are all right on phosphor bronze that is not to be rolled down to less than 0.2 inch thick. If such metal is rolled down to 0.05 inch there is trouble.

Two-ton soft-coal reverberatory furnaces are satisfactorily used in Wales on 2-to-1 yellow brass, with a melting loss of 4 per cent. There is no trouble from not getting the proper analysis nor from pouring by means of a ladle.

Reply 204, subdivisions 1, 32.—The open-flame furnace has a double chamber. It gives a very uneven mixture and a large percentage of oxidation.

Our previous figures giving the proportion of coke used to metal melted were in error. I arranged to keep a careful record of one day's operations with our eight furnaces, with the following results:

Record of one day's operation with eight furnaces.

Furnace No.	1	2	3	4	5	6	7	8
Metal melted .... pounds..	444	455	416	577	386	261	192	164
Coke used .... do....	267	263	262	342	233	256	152	162
Coke used per hundredweight of metal .... do....	60	57	62	59	60	98	79	99

A total of 2,895 pounds of metal was melted with 1,937 pounds of coke, or about 66 pounds of coke to 100 pounds of metal.

I am unable to give the percentage of loss in melting separately for coke and oil furnaces.

About 0.4 per cent of our melt is yellow brass, the rest red brass or leaded bronze.

We estimate the oil consumption per 100 pounds of heavy scrap melted to be 1 to 1¼ gallons.

[The above figures represent an average melt per furnace per day of only 362 pounds, or less than 2 heats per furnace, against the normal estimated speed of 4 heats per day reported in the table (subdivision 1). Thus the furnaces were not used to capacity, a practice that may account for the low fuel efficiency. It is to be noted also that furnaces 6, 7, 8, with only a single heat per day, or in the case of No. 6, with probably two small heats, show much poorer results than those running on 2 or 3 full heats. Five ounces is an unusually low oil pressure for an open-flame furnace.]

Reply 205, subdivision 13.—[The data for reply 205 are not taken from a reply to the list of questions sent out, but are tabulated for comparison from a paper by Hughes.[a]

The gross melting loss on an alloy consisting of 85 per cent copper, 10 per cent tin, and 5 per cent lead, is given as 0.9; on one consisting of 84 per cent copper, 5 per cent zinc, 8½ per cent tin, and 2½ per cent lead as 0.8 and 0.9; on pure copper as 0.8 per cent, and on an alloy consisting of 58 per cent copper and 42 per cent zinc as 2.9 per cent. The proportion recoverable from skimmings is given as 0.75 per cent.

The coke used showed the following analysis: Carbon, 89.24 per cent; sulphur, 0.86 per cent; ash, 9.35 per cent; moisture, 0.55 per cent. The pressure on the forced draft was 1½ to 2 ounces. The crucible life is the average on 45 crucibles.]

Reply 206, subdivision 1.—We prefer hard coke to gas-house coke. Most of our output is an alloy consisting of 87 per cent copper, 11 per cent tin, and 2 per cent zinc, but about 10 per cent is an alloy consisting of 70 per cent copper, 26 per cent zinc, and 4 per cent lead, so that the average composition of the total melt for which fuel and loss figures are given will be about that of a red brass with 3 per cent of zinc.

[a] Hughes, G., Nonferrous alloys in railway work; Jour. Inst. Met., vol. 6, 1911, p. 96; Metal Ind., vol. 9, 1911, p. 426; Castings, vol. 9, 1911, p. 13.

MISCELLANEOUS DATA.

[The data contained in many replies were so meager owing to absence of records that the conditions were not sufficiently defined to make the data comparable with those tabulated. Such replies appeared to be chiefly from small foundries using coal or coke furnaces. What data could be gleaned from these, as well as some fragmentary data collected on visits to plants that did not give complete replies, are presented below.]

A.—Round pit coal furnaces used; No. 10 to No. 60 crucibles; 2 heats in 10 hours; crucible life 30 to 35 heats. Have tried gas, but find it hard on crucible. Coal is easier on crucible and costs less.

B.—Round pit forced-draft coal furnaces used; No. 25 and No. 40 crucibles; 4 heats in eight hours; average crucible life, 25 heats; coal used per furnace per day, 150 pounds; furnaces relined every two months; all ingot metal used; bronzes of varying composition.

C.—We have been running our brass furnaces, which are of the ordinary pit-furnace type, for several years with the ordinary chimney draft, and have had rather poor results. About a couple of months ago we changed some of our furnaces and put a suction draft on them by coupling an exhauster to the chimney. This resulted in great improvement over the old way of running the furnaces, in that we may get from 5 to 6 heats a day, whereas before the change we had difficulty in getting 3 heats. However, we have not run these furnaces long enough to be able to give exact results that would be useful in a publication such as you anticipate making.

D.—Round pit oil furnaces used; 18 inches inside diameter, 26 inches deep; No. 65 to No. 100 crucibles; oil burner takes oil at 32 pounds; a small proportion of compressed air at 30 pounds is used to spray the oil; air at low pressure for combustion; combustion air preheated in horizontal flue. One man handles our four furnaces. The furnaces are used only for our own repairs and renewals.

E.—Natural-draft pit furnace used; No. 40 crucible; charge 60 to 100 pounds; 2 heats a day; crucible life 30 to 35 heats; reline once a year; melting loss 1 to 2 per cent, according to heat and composition.

F.—Round pit coal and coke furnace used; No. 40 crucible; 2 to 3 heats in eight hours; furnaces relined or repaired every six months; crucible life about 30 heats.

G.—Natural-draft pit coke furnace used; 36 inches deep, 18 inches inside diameter; No. 60 crucible.

H.—Tilting oil furnace used; No. 60 crucible; air and oil pressure each 4 to 6 pounds; 7 heats a day.

I.—Natural-draft coke furnaces used; No. 18 and No. 25 crucibles in three furnaces; No. 50 crucible used in one. We melt yellow brass.

J.—Round natural-draft coke furnaces used; 36 inches deep, 16 inches inside diameter; No. 20 to No. 80 crucibles; 2 heats in 10 hours; 50 to 90 pounds of coke per furnace per day; 100 to 200 pounds of metal per furnace per day; furnaces relined once a year; use waste heat to heat a core oven.

K.—Round natural-draft coke furnaces used; 18 inches inside diameter; No. 40 to No. 60 crucibles; 2 heats in 10 hours; furnaces repaired as needed; rebuilt every 24 months; average crucible life, 20 heats.

L.—We use only round coke furnaces; fire-brick lining; diameter inside of lining, 20 inches; 22 inches deep; cast-iron cover.

We melt only nonferrous, white metals. Capacity of each furnace, 2,000 pounds per day of nine hours. Gross loss from oxidation, $1\frac{1}{2}$ per cent. Redeemed from skimmings, about one-half of the gross loss, leaving the net loss about 0.75 per cent.

M.—Coal furnace used; No. 50, No. 60, and No. 70 crucibles; 2 heats in $9\frac{1}{2}$ hours; crucible life 12 to 25 heats.

N.—We note that some of your questions refer to the utilization of waste heat from brass-melting furnaces. This matter has been in the writer's mind for some two or three years, and there certainly is a chance for very great saving in the average brass foundry.

Some three years ago we were operating 20 pit furnaces, using hard coal as fuel, and at that time we ran for about one week a test that showed stack temperatures at various times during the day The writer has endeavored to locate the records of this test, but his search fails to reveal them. However, it is very clear that the result of the test showed that between the hours of 9.30 a m. and 5.30 there was heat enough escaping through our stack to represent approximately 150 steam horsepower. We did not figure this ourselves, but we had a local engineer go over this matter for us, and he assured us of these figures.

Within the last 12 or 18 months, we have steadily changed from our pit furnaces using hard coal to various types using fuel oil. We are at present using about 3,000 gallons of fuel oil per week, and it is obvious that if there is any means of utilizing the waste heat the saving will be worth while.

We can not give you dimensions of our furnaces as we have various sizes and reline them according to the class of work that we are running, which also determines the size of pot that we use for melting.

Size of crucible varies according to the grade of work handled in the foundry. When we are running light work we melt in No. 40 or No. 60 crucibles; when running heavy work we melt in No. 80 or No. 100 crucibles. This refers to the pit furnaces. In our one tilting furnace we use a No. 275 crucible.

The coal is burned with natural draft. We have a stack about 70 feet high, which gives us very good natural draft.

Our oil burners were first installed on a high-pressure system which operated under 10 pounds of air and 10 pounds of oil. On account of the extreme noise of this system, we have recently started to change over to low pressure which we find just as economical and much more quiet. On the new system our air is operated with about 6 to 10 ounce pressure, and the oil at 10 pounds.

One operator can handle three to four furnaces, according to the number of heats required per day and the size of pots used.

Burners consume approximately 45 gallons of oil per day on the average in 8 or 9 hours.

Number of heats which we take from our furnaces will vary from 4 to 6 per day.

We run our furnaces between 8 and 9 hours per day on the average.

Our furnaces are relined approximately every two months. This period varies, however, according to the service to which they are subjected. Besides this we patch our linings approximately once in two weeks. For patching we use a mixture of half common fire clay and half carborundum fire sand. This mixture is moistened with water and a small percentage of silicate of soda.

Crucibles last approximately 30 heats on brass. They last longer in the oil furnace when using low-pressure air than when using high.

O.—Coal furnace used; repaired yearly; crucibles No. 16 and No. 18, 4 heats per day of 9 hours; crucible life 30 heats.

P.—Two round furnaces used; 12 by 20 inches and 14 by 22 inches; gas-house coke; No. 14, No. 18, No. 40, and No. 70 crucibles; from 3 to 7 heats [probably from both furnaces together] in 9 hours; relined every six months to one year; crucible life 33 heats.

Q.—Natural-draft coke furnace used; crucible holds 30 to 60 pounds; life about 40 heats.

R.—[A brass rolling mill replies as follows.]

We use entirely round fire-brick crucible furnaces, fired with anthracite coal, melting all sorts of copper alloys, ranging from pure copper to 60 per cent copper and 40 per cent zinc; also various grades of German silver and cupro nickel.

In regard to the matter of round as compared with square melting furnaces, the square furnaces are a little easier to build and maintain, as they can be laid up with ordinary brick, whereas the round furnaces require special tile. If properly handled there is little difference between the fuel consumption of the two types; in fact, we have no figures indicating a direct comparison with the round furnace. We believe it is easier to be sure of not using an excessive amount of fuel when we have one kind of alloy being melted always in the same size crucible. Where it is necessary to vary the size of the pots and to use various alloys having different heats of pouring there is very little to be gained in using the round fires. The round fire carries a uniform thickness of fuel all the way around the pot. The square fire carries the fuel mostly in the corners.

I think you will be able to see from the above that the question as to which kind of fire uses the most fuel depends entirely upon the proportioning of the size of the furnace to the size of the pot, and, also, as to the condition of repair in which the furnaces are kept.

[Later, in conversation during a visit to this plant, the statement was made that properly porportioned round furnaces were found by actual test to be more economical of fuel than properly proportioned square furnaces.] Five-tenths per cent of the melt is recovered from the ashes. Draft, 2 inches of water at base of stack.

S.—[Another rolling mill visited used square furnaces, No. 60 crucibles, hard coal, and natural draft. Separate flues ran to the main stack from every three furnaces, to equalize the draft. No records were kept. The estimated net melting loss was 1.5 per cent on yellow brass and 0.75 per cent on German silver. The operator estimated that 25 pounds of coal per 100 pounds of metal melted was used. He stated that it was possible to pour metal for heavy rolling ingots from small crucibles into a larger one and from that into the mold, and consequently that on a good deal of rolling-mill work it would be possible to melt in large quantities and to pour the metal satisfactorily if there were some way of melting a large quantity without too much loss of zinc. The temperature drop in the double pouring was thought to be more objectionable than the danger of oxidation.]

T.—[Another rolling mill visited has tried tilting-crucible furnaces with a capacity of 900 pounds, fired with cold producer gas. This type had been abandoned because of the high expense for upkeep of crucibles, etc., but not because of the zinc losses, although these were higher than in the square, coal-fired, pit furnaces now being used. With much of the rolling-mill work there is no trouble in pouring by means of a ladle and probably all of that kind of product could be so poured. One representative of this firm had the impression that the solution of the problem of melting yellow brass will be the use of a one-half to 4 ton reverberatory furnace fired with producer gas. He stated that in England a 1-ton, soft-coal reverberatory is used for brass, composed of 60 per cent of copper and 40 per cent of zinc, with the avowed object of getting more perfect alloying, a lower zinc loss, and a composition varying less from that desired, than can be obtained in small crucibles.

The chemist of this firm stated that according to his estimates the figure of 7,500 pounds of zinc lost per day up the stack of the rolling mills of Waterbury, Conn., as given by Parsons[a] should be nearer 15,000 pounds, and that he estimates that in Waterbury the total daily zinc losses, including those in pickling, are over 20,000 pounds.]

U.—Square furnaces used; inside dimensions, 18 by 18 by 30 inches; fuel, 72-hour uncrushed coke, crushed at foundry with hammer to proper size to fit snug; No. 30 to No. 150 crucibles used, all in same size furnace; metal put in crucible before putting in fire; no metal added while in fire; No. 125 crucible holds about 250 pounds charged in this way; crucible life 12 to 18 heats; various bronzes melted; no data kept on metal losses or fuel consumption.

[a] Parsons, C. L., Notes on mineral wastes: Bull. 47, Bureau of Mines, 1912, p. 21.

V.—We use open-flame oil furnaces, with capacities rated at 500 and 1,000 pounds and natural-draft pit coke furnaces with No. 100 crucibles.

The oil is "distillate," and has a specific gravity of about 0.87. It is fed at a 20-pound pressure, the air pressure being 8 to 16 ounces. We melt an average of 4,000 pounds in an 8-hour day in all furnaces, one tender handling them all. We can get up to 8 heats in the oil furnaces, which are relined every three months. In the coke furnaces the crucibles average 30 heats. We use 2 gallons of oil per hundredweight of metal melted; no data on coke. The gross melting loss [alloy not given, but probably red brass] is about 5 per cent, but we have no definite data. The open-flame oil furnace is best for speed, and the coke furnace for tensile strength, although we have remarkably good results on tensile strength with the open-flame furnace.

W.—[A gas company replies as follows.]

The tests on melting brass with city gas were unsatisfactory. The gas consumption was low enough but the loss was over 10 per cent, and we believe that this was due to our ignorance of the furnace and its operation. However, we are going to try to run some further tests and take advantage of the experience gained in the first tests.

In test runs with this furnace in another city the loss was very low. We believe that with proper operation of the furnace our loss will also be low. In this case we shall be able to melt brass cheaper than with either coal, coke, or oil at the present market prices for those fuels.

X.—Natural-draft pit coke furnaces of two sizes and forced-draft tilting coke furnaces are both used. The pit furnaces are all 36 inches in depth; those for the No. 70, No. 100, and No. 150 crucibles are 19 inches inside diameter, and those for No. 300 are 25 inches inside diameter. The tilting furnaces are 31 inches deep, 23 inches inside diameter, and take a special crucible holding about 400 pounds. A little anthracite coal is used with the coke. The following data are lumped for both types of furnaces, no separate data being at hand:

One furnace tender handles five furnaces, getting an average of 3 heats in a 10-hour day. The fuel consumption is 75 pounds of coke and 8 pounds of coal per hundredweight of metal melted. The average crucible life is 27 heats, and the gross melting loss is 2.7 per cent. Furnaces relined twice a year. There is no great difference in the quality of metal from the two types of furnaces. The forced-draft tilting furnaces are not hooded, and give off objectionable zinc smoke into the foundry.

DISTRIBUTION OF FURNACES REPRESENTED IN REPLIES.

In all, 28 States were represented by the replies listed in the table. In the 63 replies on natural-draft coke furnaces 18 States were represented; half of the replies were from Pennsylvania, Ohio, and Michigan, the rest being from widely scattered States. Over half of the replies on square pit coke furnaces were from Pennsylvania, and all but one of the others were from adjacent States.

The four replies on forced-draft pit coke furnaces were from four widely separated States.

Of the dozen replies on forced-draft tilting coke furnaces, one-third were from Pennsylvania, one-third from New York, and the other four replies from four different States.

Of the 49 replies on natural-draft anthracite-coal furnaces, 80 per cent were from New England or the Hudson River Valley, only 12 per cent being from firms outside of New England and New York. Of the replies on square coal furnaces, 75 per cent were from Connecticut. Of the replies on forced-draft pit anthracite-coal furnaces, 90 per cent were from the Chicago district.

The three replies on soft-coal reverberatory furnaces were from three States.

Three replies on city-gas furnaces represented two States, whereas replies on natural-gas furnaces were all from Ohio and Pennsylvania, over two-thirds being from Ohio.

The oil furnaces show the widest distribution, 33 replies on pit oil furnaces being from 13 States, and 31 on tilting oil furnaces from 15 States, whereas the 40 replies on open-flame oil furnaces were from 18 States. The six replies on oil-fired reverberatories came from five States. Oil furnaces of all classes were represented by 24 of the 28 States from which replies were received.

To summarize, the oil furnaces appear to be the most widely distributed, the coke furnaces being next. The natural-gas furnaces are of course localized. The hard-coal furnaces, particularly the square natural-draft furnaces and the forced-draft pit furnaces show remarkable localization, as do the square pit coke furnaces. Localization of the square, natural-draft furnaces is due to the conservatism of the rolling-mill industry; localization of the forced-draft, pit, and the square, pit, coke furnaces is probably due to the success of the firms first using those types in certain localities.

OUTPUT OF DIFFERENT TYPES OF FURNACES.

The pit furnaces reported outnumber the tilting furnaces, but considering the larger capacity of the tilting or tapping furnaces of all types and the larger size of the firms using tilting or tapping furnaces, it is probable that the output of all but yellow brass from those types is considerably larger than that from pit furnaces. However, the general use of pit furnaces by the rolling mills on their large output will cause the greater part of the total of all brasses and bronzes melted to be from pit furnaces.

Although there are a third more replies on oil furnaces than on coke furnaces, and nearly twice as many as on hard-coal furnaces, the use of hard coal by so many of the large rolling mills will probably make the output melted by coal equal to or greater than that melted by oil. As so many of the firms using coke run a large number of furnaces, it seems probable, on the basis of the replies received, that the quantity of metal melted by coal, by coke, and by oil will not be greatly different.

TYPES OF PLANTS REPRESENTED.

Jobbing shops, with rare exceptions, use pit furnaces, the crucibles holding less than 300 pounds. A few of the large manufacturing plants, outside of the rolling mills, still use pit furnaces, but these are, almost without exception, those whose castings are so small or so thin that the drop in temperature due to pouring into a ladle from a tilting or tapping furnace can not be allowed. The great majority

of the manufacturing plants whose aim is large production use tilting or tapping furnaces on account of their greater speed. Few of the users of tilting coke furnaces, tilting crucible oil furnaces, tilting open-flame oil furnaces, or reverberatory, oil-fired, or coal-fired furnaces come into the jobbing class. Most of the large manufacturers, except the rolling mills, use oil on account of the great speed of melting possible with its use, and in this connection it should be noted that the open-flame, oil furnaces seem to come the nearest to meeting the needs of the large manufacturer who must melt huge quantities of red brass.

TYPES OF ALLOYS MELTED.

All of the commercial types of furnaces, with proper handling, are largely and successfully used in melting bronzes, red brass, and other alloys low in zinc. On account of the volatility of zinc, the furnaces mostly used for yellow brass and manganese bronze are of types that do not involve the passage over the surface of the metal of large volumes of products of combustion at high velocity; that is, natural-draft coal or coke furnaces are more largely used for high-zinc alloys than forced-draft furnaces, crucible oil furnaces coming next, and open-flame oil furnaces or reverberatories last.

However, on alloys containing 15 to 20 per cent of zinc ("half yellow, half red") the open-flame oil furnaces are largely used. In these the great speed of melting compensates to a large extent for the metal loss, when all the cost factors are considerd. The proportion of zinc volatilized from a given weight of metal melted will depend on the temperature to which the metal is raised, which is chiefly determined by the size and nature of the mold into which the metal is to be poured, the extent of molten-metal surface exposed, the total time the metal is held at a high temperature, and the rapidity with which the zinc vapor is swept away by the stream of gases (products of combustion) flowing over the surface of the metal, as the main variables. Hence, great speed of melting may compensate for rapid flow of gases, for although a considerable amount of zinc may be swept away in a given time, yet the volatilization of a rather great weight of zinc per unit of time for a short time only may mean a lesser percentage of the total melt than a smaller weight volatilized per unit of time over a much longer period.

On "half yellow, half red" alloys the balance seems to be in favor of rapid heating of large charges even with rapid gas circulation, the percentage of zinc volatilized probably being less than with slow heating of small charges; that is, at the vapor pressure of alloys containing around 20 per cent of zinc, great speed of melting will outweigh the effect of the rapid current of gases of combustion necessarily formed in obtaining the high melting speed.

On yellow brass or manganese bronze, with a zinc content of 30 to 40 per cent, the melting losses reported on the furnaces involving

rapid flow of waste gases show in general a larger zinc loss than in those with less rapid flow and slower heating. This result does not necessarily mean that the oil or gas furnaces, of either crucible, open-flame, or reverberatory types, may not be more economical in the long run, even on alloys high in zinc.

From the point of view of an engineer, the efficiency of a furnace is the ratio of the heat units absorbed by the metal in useful work to the heat units supplied in the fuel. What a foundry superintendent means by "the efficiency of a furnace" is not heat efficiency alone, though that is a factor, but cost efficiency. On a cost-efficiency basis the most efficient furnace is the one that shows the lowest total cost, per pound of metal melted, for fuel, metal lost in melting, bad castings due to metal spoiled by the furnace, upkeep, repairs, labor, interest, and overhead charges; at the same time the furnace must produce, from the alloy melted, metal of a satisfactory quality and in quantities suitable for the purpose of the foundry.

Any one factor may throw a furnace entirely out of consideration for a particular foundry. If a certain fuel is not readily obtainable in a certain locality, furnaces using that fuel do not enter into that foundry's choice. If a certain furnace has a much higher first cost than another less efficient furnace, a firm of small capital may not be able to invest in the more efficient type. If a plant is located in the heart of a city, where space is at a premium, it may be necessary to install a furnace requiring less floor space than a more efficient type. Again, a jobbing foundry requiring small quantities of a large number of alloys may be forced to use a larger number of smaller and less efficient furnaces than would a large manufacturing plant needing large quantities of one kind of alloy.

There is also a distinction between the efficiency of a furnace and the efficiency of its use. A furnace, if properly handled, may be capable of turning out metal with low fuel consumption, low repair or crucible cost, and low loss in melting, and yet may be so used as to be in all these respects distinctly inefficient, whereas another furnace, at its best, may not be capable of as good a performance in these respects as the first furnace at its best, and yet, if more "fool-proof," may give better results. Hence, one must consider not only efficiency under ideal conditions, but how readily ideal conditions can be obtained in the use of various types.

The problem does not concern the furnace only; the real problem is the economical production of molten metal of a satisfactory quality. The comparison is not merely one of furnace A and furnace B, but of foundry procedure with furnace A and foundry procedure with furnace B.

In order to get the proper point of view, then, it will be well to consider the general problem of combustion, and some properties of brass in their application to the general problem.

GENERAL FACTORS AFFECTING OPERATION OF BRASS FURNACES.

COMBUSTION.

One pound of carbon burned to carbon dioxide (CO_2) gives 14,540 British thermal units, but if burned only to carbon monoxide (CO), it gives only 4,380 British thermal units, or only about 30 per cent of its full value. Oil burned to CO gives about 60 per cent of its full value.[a] Therefore, as regards heat development, the more complete the combustion is, the better. However, to obtain complete combustion to CO_2, it is ordinarily necessary to supply considerably more than the theoretical proportion of oxygen, twice the theoretical being considered fair boiler-room practice.

All the excess air has to be heated to the temperature of the escaping products of combustion. In boiler-room practice the aim is to get no CO, or only traces, with the least possible air excess.

OXIDIZING AND REDUCING ATMOSPHERES.

In brass melting the air excess must be kept low enough to give a flue gas that is not sufficiently oxidizing, when it comes in contact with the metal, to produce appreciable oxidation. Copper, zinc, tin, and lead, the constituents of commercial brasses, are all readily oxidizable at the temperature to which they have to be heated for melting and pouring. Oxidation not only results in loss of metal, actually burning it to a dross that has to be skimmed off, but any oxides that do not happen to separate well and are not skimmed off are taken into solution by the metal or are mechanically held by it. These are a source of weakness in the metal and may cause it to fail under hydraulic test, owing to its porosity due to oxide inclusions. It is always recognized that it is essential to prevent or to remedy oxidation. The prevention usually comprises a layer of charcoal over the metal, which produces a layer of carbon monoxide directly over the surface; the remedy is deoxidation, as by phosphorus or boron suboxide, or by zinc or manganese contained in the charge itself.

It is almost certain that carbon monoxide is harmless to molten brasses and bronzes. It is even more certain that oxygen is harmful, whereas carbon dioxide may be inert or may be oxidizing. It is oxidizing to zinc.

All melters strive to maintain a "reducing atmosphere" and to avoid an "oxidizing atmosphere" over the metal. Just how high in carbon monoxide and low in oxygen the gases have to be to show the beneficial "reducing atmosphere" and how low in carbon monoxide and high in oxygen they have to be to form the harmful oxidizing atmosphere is unknown, as no systematic study of the furnace gases from brass furnaces has been made.

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[a] Krom, L. J., Development of melting furnaces: Metal Ind., vol. 7, 1909, p. 289.

Demesse[a] and Grebel[b] suggests passing the products of combustion over molten lead, and states that if the gases are oxidizing the lead will be covered with a film of oxide; if the gases are reducing, the surface of the lead will be bright.

It is certain, however, that the carbon monoxide must be so high and the oxygen so low that one can not, in ordinary furnaces, hope to maintain a sufficiently reducing atmosphere without sacrificing a good many heat units through the burning of carbon to CO instead of to CO_2.

VOLATILITY OF ZINC.

In dealing with zinc-containing alloys, the volatility of the zinc is also a factor. Pure zinc boils at about 920° C. (about 1,690° F.)[c] and has a very appreciable vapor pressure at a temperature not far above its melting point, 418° C. (785° F.).

Molten copper-zinc alloys, owing to the high vapor pressure of zinc, lose zinc readily at high temperatures. Some rolling mills cast yellow brass at a temperature very close to the boiling point, holding the crucible in the furnace until signs of actual ebullition are observed. One foundry making "half yellow, half red" sand castings of such a size and shape that they are extremely thin and difficult to run does not pour the metal until the furnace tender can feel the metal "jump" when an iron bar is poked into the melt; that is, when the metal is almost at the boiling point.

In such cases the loss of zinc is readily apparent, the volatilized metal burning to clouds of white zinc oxide as soon as it reaches the air. Even at much lower temperatures considerable zinc fume is evolved.

The rate of loss of zinc depends on the vapor pressure of the zinc in any given composition of brass at various temperatures, on the maximum temperature reached, on the rate of heating to this temperature, on the volume and velocity of the gas flowing over the surface, that is, on how nearly equilibrium is reached between melt and vapor, and on the rate of diffusion of zinc from the body of the melt into the surface that is losing zinc.

The temperature required is fixed by the size of the casting to be made and by the material of the mold. The vapor pressure of the brass used is fixed by a natural law, as is the rate of diffusion. Hence the only variables over which the foundryman has any control are (1) the rate of heating to the proper pouring temperature, (2) whether the metal is taken from the furnace as soon as it is ready or allowed to wait there or allowed to get too hot, so as to require

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[a] Demesse, J., Le comburimètre: Rev. Chem. App., vol. 2, 1913, p. 99; Chem. Abs., vol. 7, 1913, p. 3254.

[b] Grebel A., La comburimètrie des combustibles gazeux: Le Génie Civil, vol. 61, 1912, p. 260.

[c] LeChatelier, H., The measurement of high temperatures, 1912; translated by G. K. Burgess, p. 438; Barus, C., The pressure variations of certain high-temperature boiling points: Phil. Mag., ser. 5, vol. 29, 1890, p. 141.

cooling, and (3) the volume and rate of flow of gases over the surface of the metal.

With a given rate of flow of gases through the furnace, it is obvious that the more rapid the rate of heating, the less the zinc that can be carried off as vapor by the gases. On this point the statements given in the notes on Replies 8, 15, 140, and 201 are of interest. With a given rate of heating, it is clear that the less the volume and the less rapid the flow of gases over the metal, the less is the loss. In a furnace closed absolutely tight, with no passage of gas, there would be no loss of zinc, after the small quantity had been given off that is necessary, at the furnace temperature and pressure, to saturate the vapor space existing in the furnace, no matter how long the metal might be held in the furnace. Electric heating is the only known method of heating that will approach this ideal condition.

Whether the gas flow or the rate of heating has the more powerful influence will depend on the vapor pressure of the alloy melted.

VAPOR PRESSURE OF MOLTEN BRASS.

Little accurate information is available on the vapor pressures of the copper-zinc alloys.

Hansen[a] made some measurements of the vapor pressures of two brass alloys, one of which contained 76 parts copper and 24 parts zinc, and the other, 55 parts copper and 45 parts zinc, with the following results:

Vapor pressures developed by two brass alloys at various temperatures.

COPPER 76 PARTS, ZINC 24 PARTS.

Temperature.[a]		Pressure developed.
°C.	*°F.*	*Atmospheres.*
1,000	1,830	0.29
1,084	1,985	0.66
1,150	2,100	1.18

COPPER 55 PARTS, ZINC 45 PARTS.

900	1,650	0.24
950	1,740	0.44
1,000	1,830	0.72
1,100	2,010	1.55

[a] In these results, an allowance for possible error of ±15° for centigrade readings and of ±30° for Fahrenheit readings should be made.

These data are plotted in figure 1, the plot being made to show both the average values and the limits of accuracy given by Hansen. The curves are approximately parabolic in form.

[a] Hansen, C. A., Electric melting of copper and brass: Trans. Am. Inst. Metals, 1912, p. 111.

Interpolating on these curves, the boiling point (vapor pressure at 1 atmosphere) of the alloy containing 76 parts copper and 24 parts zinc is 1,130° C. (± 15°), or 2,070° F. (± 30°), and of the alloy containing 55 parts copper and 45 parts zinc, 1,040° C. (± 15°), or 1,905° F. (± 30°).

Hansen's work was done in a vacuum electric furnace, at constant temperature, and observation of the boiling point was made possible by altering the pressure. By his method the temperature is calculated from the power consumption of the furnace, a method that can not give close temperature figures, as considerable latitude is left to the operator in his decision as to just what pressure corresponds to actual boiling.

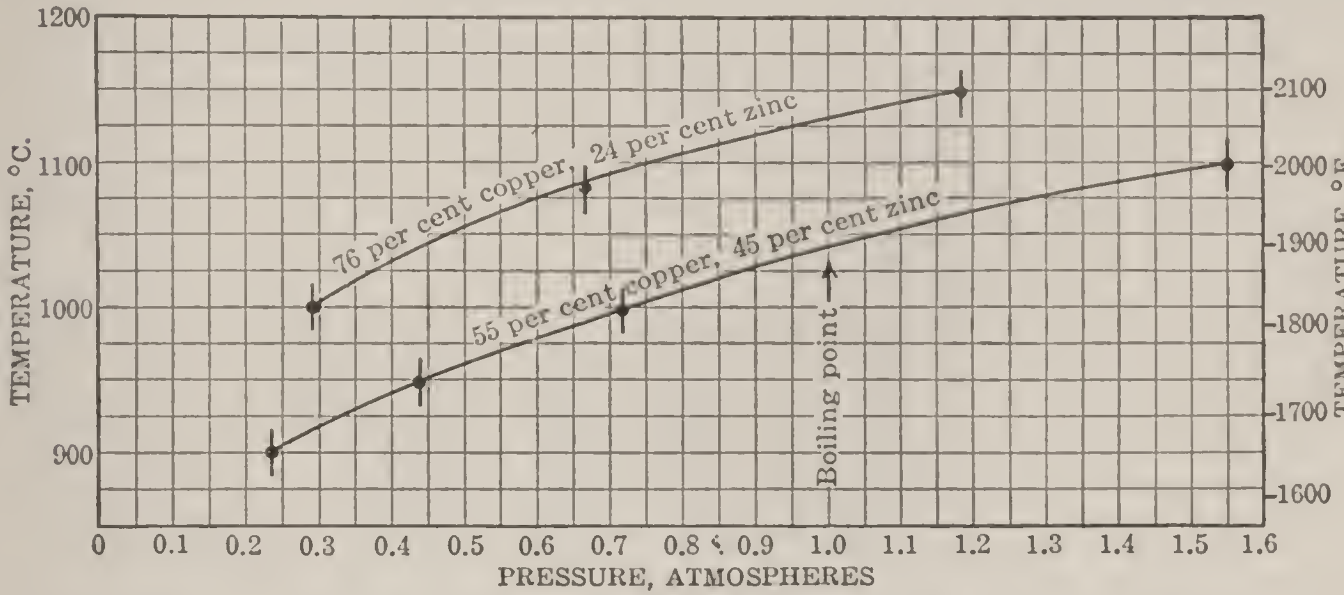

FIGURE 1.—Vapor pressures of copper-zinc alloys. (Plotted from Hansen's data.) The curves show how the partial pressure of the zinc vapor—that is, the tendency of the zinc to volatilize—increases as the temperature increases, and, for the two cases shown, illustrates the fact that for any given temperature the higher the zinc content the higher the vapor pressure. The vertical lines through the plotting points show the limits of accuracy (±25° C.) that Hansen gives for his determinations. Note that the alloy with 24 per cent of zinc has to be raised to 1,100° C. to become as volatile as is that with 45 per cent of zinc at 1,000° C.

In an unpublished communication Hansen states that with an alloy consisting of about 81 per cent of copper and 19 per cent of zinc, there was gentle movement of the melt at 1.05 atmospheres, and at 0.94 atmosphere globules of metal shot up more than 8 inches above the surface of the melt.

The boiling point was taken as 0.95 atmosphere. The power consumption was equivalent to a temperature of 1,300° C. (±15°), or 2,370° F. (±30°). This would give about 1,310° C. (±15°), or 2,390° F. (±30°), as the boiling point at 1 atmosphere.

Fery [a] gives a curve for the "fractional distillation" of an alloy consisting of 63 per cent copper and 37 per cent zinc, which shows a flat part between 1,030° and 1,100° C. or 1,885° and 2,010° F. This observation was made with a radiation pyrometer and may be low,

[a] Fery, M., Determination des points d'ebbulition de cuivre et de zinc: Ann. chim. phy., 7th ser., vol. 28, 1903, p. 428.

owing to deviation from "black-body radiation" and to zinc fumes between the melt and the pyrometer, cutting down the radiation. The observations were taken very rapidly, the rate of heating (an electric-arc furnace was used) being over 1,000 ° C. in 7 minutes, and hence is probably not extremely accurate.

J. M. Lohr, of the Bureau of Mines, has obtained a few hitherto unpublished approximate figures as to the boiling points of various copper-zinc alloys by heating the alloys in an electric-resistance furnace. Observations of time and temperature were made, the temperature being read with a base-metal thermocouple immersed in the metal without protecting sheath, the boiling point being taken as the beginning of an approximate flattening of the time-temperature curve. The results of the tests were as follows:

Boiling points of various copper-zinc alloys.

Composition of alloy.		Boiling point.[a]	
Copper.	Zinc.		
Per cent.	*Per cent.*	*° C.*	*° F.*
84.5	15.5	1,365	2,490
77	23	1,220	2,230
75	25	1,220	2,230
74.5	25.5	1,220	2,230
67	33	1,120	2,050
65	35	1,100	2,010
56.5	43.5	1,050	1,920
55.5	44.5	1,050	1,920

[a] Allowable error ± 20° for centigrade readings, and ± 40° for Fahrenheit readings.

S. J. Popoff, at Cornell University, found that an alloy that was about 82 parts copper and 18 parts zinc boiled at 1,300° C. (±25°), or 2,370° F. (±50°).

None of the boiling-point figures is to be taken as final, but they will serve to give an idea of the approximate shape of the curve. The boiling point of copper was determined by Greenwood[a] as 2,310° C. (4,190° F.), and Burgess[b] gives the boiling point of zinc as 920° C. (1,690° F.). The figures on boiling points from the above sources are plotted in figure 2, together with the melting-point curve as determined by Shepherd.[c] The figures may not represent true boiling points, but they at least show the temperature at which a very rapid volatilization of zinc occurs.

The vapor-pressure curve for any given alloy will not have its origin at the melting point of that alloy, but somewhat below it.

Bengough and Hudson[d] determined the rate of volatilization of zinc from a sample of brass consisting of 70 per cent of copper and 30 per cent of zinc. The sample was annealed for 2½ hours at 920°

[a] Greenwood, H. C., The boiling points of metals: Trans. Faraday Soc., vol. 7, pt. 2, 1911, p. 1[illegible]1.
[b] Burgess, G. K., Measurement of high temperatures, 1912, p. 438.
[c] Shepherd, E. S., The constitution of the copper-zinc alloys: Jour. Phys. Chem., vol. 8, 1904, p. 423.
[d] Bengough, G. D., and Hudson, O. F., The heat treatment of brass: Jour. Inst. Metals, vol. 4, 1910, pp. 101, 110.

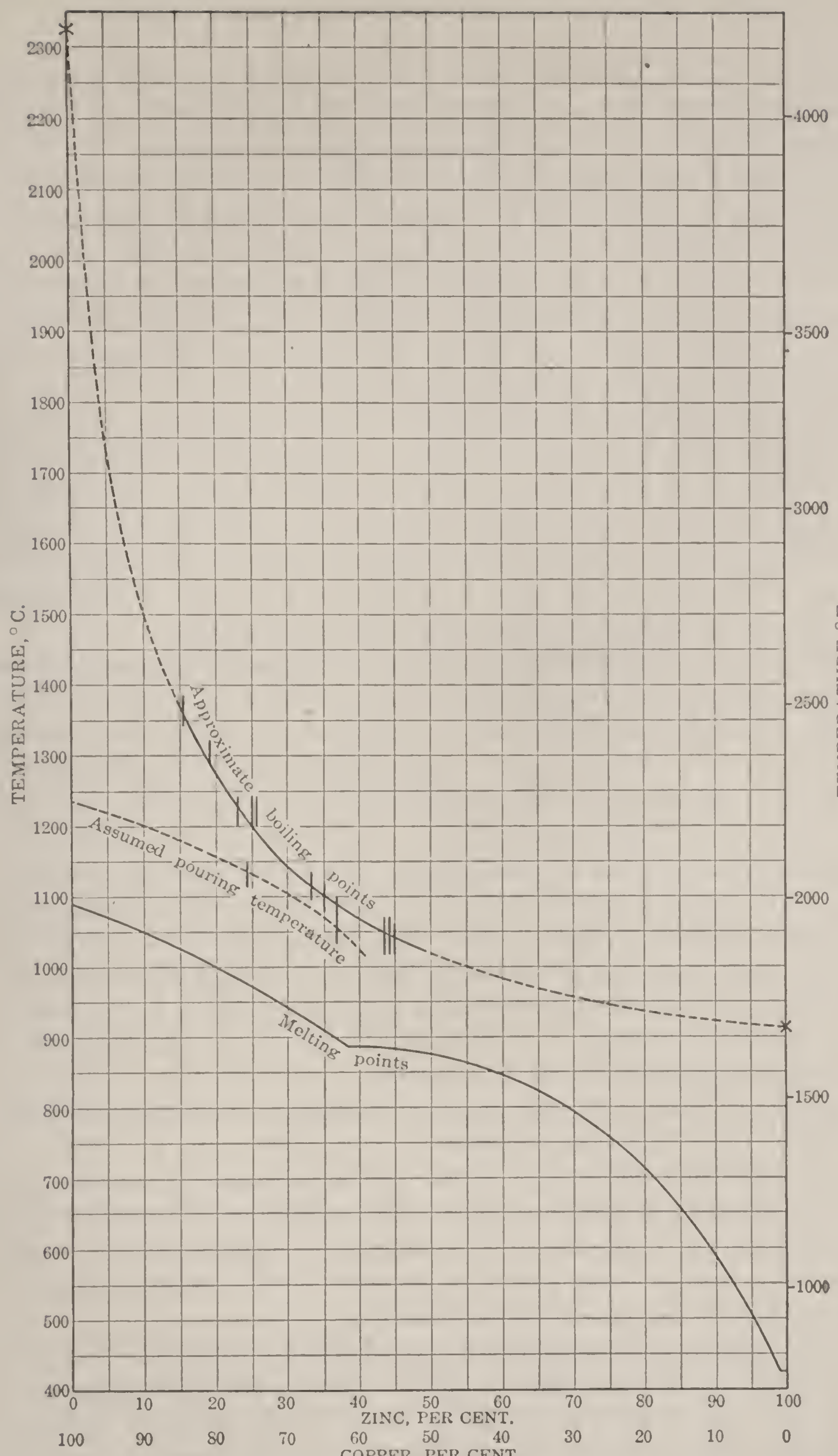

FIGURE 2.—Approximate boiling points and assumed pouring temperatures of copper-zinc alloys. The melting-point curve is from Shepherd. The pouring temperature is assumed at 150° C. above the melting point, and the approximate boiling-point curve is plotted from all available data, the limits of error given by the various workers being shown by the length of the vertical lines through the plotting points. The boiling points of pure copper and pure zinc are the figures of Greenwood and Burgess, respectively. The nearer the pouring temperature to the boiling point, the greater the vapor pressure of zinc and its tendency to volatilize. Note that the alloys containing 30 to 40 per cent of zinc are poured when very close to the boiling point; those containing 20 per cent of zinc, when about halfway between the melting and the boiling points; and those containing 5 per cent of zinc, when only about a quarter of the way between the two points. These relations show why the loss of zinc and the trouble from "brass shakes" are higher in connection with brasses containing 30 to 40 per cent of zinc than in alloys containing lower proportions.

to 930° C. (1,690° to 1,705° F.). At the end of this time the outer one sixty-fourth of an inch of the bar had lost 5.7 per cent of zinc (nearly 20 per cent of the original proportion of zinc). On being annealed for 1 hour longer at 930° C. (1,705° F.), the outer one sixty-fourth of an inch lost 4.7 per cent of zinc; in another half an hour at 900° C. (1,650° F.), it lost 1.4 per cent, and in a half hour more, at 700° C. (1,290° F.), 0.5 per cent. Below a depth of one-sixteenth of an inch the loss was negligible, but the high loss from the outer one sixty-fourth of an inch shows that the vapor pressure is still appreciable, even with a temperature as low as 700° C.

Turner [a] heated a small quantity of brass, consisting of 63 per cent of copper and 37 per cent of zinc, to a temperature just above the melting point of copper (1,082° C.; 1,980° F.) for half an hour, in a high vacuum (about 0.007 atmosphere). All the zinc distilled off; at 1,200° C. (2,190° F.) there was only a slight volatilization of copper. The lead in an alloy containing 7 per cent of that metal was completely distilled off at 1,200° C. in a vacuum.

In a vacuum (pressure of about 0.0001 atmosphere) he obtained the first sign of sublimation of pure zinc at 375° C. (700° F.). With an alloy consisting of 60 per cent of copper and 40 per cent of zinc, the temperature above which sublimation occurred was 520° C. (970° F.); and with an alloy consisting of 70 per cent of copper and 30 per cent of zinc, sublimation occurred at 550° C. (1,020° F.).

Bassett [b] states that in annealing yellow brass there is no appreciable volatilization of zinc at 450° C. (840° F.); that volatilization becomes noticeable at 500° C. (930° F.); that at 550° C. (1,020° F.) 0.3 gram per square meter is lost in 10 hours; that at 650° C. (1,200° F.) 1.5 grams per square meter is lost in 1 hour and 5.4 grams in 10 hours; and that at 750° C. (1,380° F.) 46 grams per square meter is lost in 1 hour and 63 grams in 10 hours.

Damarçay [c] observed faint signs of volatility of zinc in a vacuum at 184° C. (363° F.) after 50 hours.

However, as vapor-pressure curves for the full range of temperatures are not available, it may be assumed for purposes of comparison that the difference in temperature between the melting and the boiling points of a brass of any given composition, will determine the significant part of the vapor-pressure curve.

It is ordinarily necessary to pour brasses and bronzes at a temperature of 100° to 200° C. (180° to 360° F.) above the melting point, in order that the mold may fill properly and the metal be free from blowholes. Lohr [d] found this to be the case in casting small test bars in heated graphite molds.

[a] Turner, T., Behavior of certain alloys when heated in vacuo: Jour. Inst. Metals, vol. 7, 1912, p. 105.

[b] Bassett, W. H., Zinc losses: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 164; Metal Ind., vol. 10, 1912, p. 239.

[c] Damarçay, E., Sur la vaporisation des métaux dans le vide: Compt. Rend., vol. 95, 1882, p. 183.

[d] Lohr, J. M., The tensile strength of the copper-zinc alloys: Jour. Phys. Chem., vol. 17, 1913. p. 23.

Bassett[a] puts the pouring temperature of "high" or yellow brass (copper and zinc ratio, 2:1), which melts at about 915° C. (1,680° F.), at 1,050° C. (1,920° F.), whereas the chemist of another rolling mill uses 1,065° C. (1,950° F.) as the pouring temperature of this alloy.

Carpenter and Edwards[b] recommend pouring castings of aluminum bronze consisting of 90 per cent of copper and 10 per cent of zinc at 80° C. above the melting point.

Karr[c] gives 910° C. (1,670° F.), as the pouring temperature for a sand casting of a brass made of 69 parts of copper and 31 of zinc. He gives 893° C. (1,640° F.) as the observed melting point of this brass, but states that the true melting point is 950° C. (1,742° F.). He used a radiation pyrometer and the observations were probably affected by deviation from black-body radiation.

Primrose[d] gives 1,100° C. (2,010° F.), as a good pouring temperature for gun metal consisting of 88 parts copper, 10 parts tin, and 2 parts zinc.

Longmuir, quoted by Karr,[e] Buchanan,[f] and Law[g] gives, as a suitable pouring temperature for gun metal, 1,070° C. (1,960° F.); for an alloy consisting of 75 per cent of copper and 25 per cent of zinc, 1,020° C. (1,870° F.); and for brass containing 60 parts copper and 40 parts zinc, 975° C. (1,785° F.).

Another pouring temperature given for gun metal is 2,300° F. (1,260° C).[h]

A brass consisting of 75 per cent of copper and 25 per cent of zinc melts at about 920° C (1,670° F.), and one consisting of 60 per cent of copper and 40 per cent of zinc at about 890° C. (1,635° F.). The melting point of gun metal, consisting of 88 parts of copper, 10 parts tin, and 2 parts zinc, as determined by Norton,[i] is about 995° C. (1,825° F.).

Reardon[j] gives 2,000° F. (1,095° C.), as the pouring temperature (from the ladle) of one lot of an alloy consisting of 73 parts copper, 18 parts zinc, 7¼ parts lead, and 1¾ parts tin, and 2,175° F. (1,190° C.), as the pouring temperature of another lot of the same alloy. This alloy will probably melt at a temperature of about 920° to 925° C. (1,690° to 1,700° F.), as Norton[k] found that an alloy consisting of

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[a] Bassett, W. H., loc. cit.

[b] Carpenter, H. C. H., and Edwards, C. A., Production of castings to withstand high pressure: Engineering (London), vol. 90, 1910, p. 871; abstracted in Jour. Inst. Metals, vol. 5, 1911, p. 327.

[c] Karr, C. P., The pouring and melting points of some high-grade bronzes: Trans. Am. Brass Founders' Assn., vol. 5, 1911, pp. 72, 77, 80.

[d] Primrose, H. S., Metallography as an aid to the brass founder: Metal Ind., vol. 8, 1910, p. 466.

[e] Karr, C. P., loc. cit.

[f] Buchanan, J. F., Practical alloying, 1910, p. 37.

[g] Law, E. F., Alloys, 1909, p. 10.

[h] See answer to question in "Shop Problems": Metal Ind., vol. 10, 1912, p. 428.

[i] Gillett, H. W., and Norton A. B., The approximate melting points of some commercial copper alloys: Technical Paper 60, Bureau of Mines, 1913, p. 8.

[j] Reardon, W. J., The manufacture of high copper castings: Metal Ind., vol. 8, 1910, p. 212.

[k] Gillett, H. W., and Norton, A. B., loc. cit.

75 parts of copper, 20 parts of zinc, 2 parts of tin, and 3 parts of lead melted at a temperature of about 920° C. (1,690° F.).

On the assumption that commercial copper-zinc alloys are poured when 150° above their melting points, the pouring temperatures of such alloys have been plotted in figure 2. It will be noted that for a zinc content of 40 to to 30 per cent, which includes Muntz metal, ordinary yellow brass (copper-zinc ratio, 2:1), and brass containing 70 parts of copper and 30 parts of zinc, and covers the zinc content of manganese bronze, although in that alloy the presence of iron, tin, aluminum, and manganese may alter the boiling point, the pouring temperature and boiling point of a given alloy as indicated by the curves are only about 25° to 35° C. (50° to 70° F.) apart. As the zinc content is decreased from 30 to 20 per cent, the curves begin to separate, until, with an alloy containing 18 per cent of zinc, the pouring temperature and boiling point are 135° C. apart.

These relations show why it has been found perfectly feasible to melt metal with a zinc content of 16 to 18 per cent in open-flame, oil furnaces[a] for at this percentage the vapor pressure of zinc is probably not much over half an atmosphere at the pouring temperature, whereas, on a 2-to-1 brass, it is nearly 1 atmosphere. Hence, with the 18 per cent alloy, the speed of melting in the open-flame furnace just about balances the effect of the greater volume of gas passing over the metal.

When the percentage of zinc is down to 5, as in ordinary red brass, although the presence of the tin and lead may complicate the vapor pressure relations somewhat, the vapor pressure of the zinc is so low that a small gain in speed of melting more than compensates for a greater gas flow that may be necessary in order to obtain that speed.

Longmuir[b] seemingly does not consider that the vapor pressure of a brass has anything to do with the proportion lost, as he states that the loss of zinc is a function of the temperature reached and not of the proportion present in the alloy. To substantiate his position, he gives the following figures:

Zinc losses in melting certain alloys.

Name of alloy.	Highest temperature reached in furnace.	Zinc in alloy.	Zinc content lost from sample.	Calculated loss of zinc from whole melt.[c]
	°F.	*Per cent.*	*Per cent.*	*Per cent.*
Red brass	2,386	10.2	28.6	2.9
Yellow brass	2,160	26.0	26.1	6.8
Gun metal	2,144	1.8	27.7	0.5
Muntz metal	1,900	40.5	19.0	7.7

[a] See Replies 2 and 104 in subdivision 33 of the table; also Hansen, C. A., Electric melting of copper and brass: Trans. Am. Inst. Metals, vol. 6, 1912, p. 113.
[b] Longmuir, P., Deoxidation of copper and its alloys: Foundry, vol. 40, 1912, p. 460.
[c] Calculated from Longmuir's figures in two preceding columns.

Before accepting Longmuir's conclusion it would seem to be necessary to know something as to the type of furnace used, the length of time each alloy was in the furnace, and whether all the melts were under the same conditions.[a]

PRESSURE OF GASES FLOWING OVER MELTING METAL.

Aside from the speed of melting, the pressure, the volume, and the velocity of the gases flowing over melting metal should be considered in regard to the loss of zinc.

Replies 2, 86 and 104 state that in open-flame oil furnaces melting alloys consisting of 16 to 18 per cent of zinc, the operators close the vents to the furnaces as much as possible in order to maintain a pressure over the metal higher than atmospheric. This procedure is now advocated in the catalogue of the makers of one furnace of this type, who say:

> In a paper entitled "On the Behavior of Certain Alloys When Heated in Vacuo," read by Prof. Thomas Turner at the London meeting of the Institute of Metals, January 16–17, 1912, the author showed that zinc could be removed from brass and other alloys very rapidly by heating in a vacuum.
>
> The results obtained in melting yellow brass in our furnaces seem to prove that the converse of Prof. Turner's experiment is also true; namely, that when alloys high in zinc are melted under pressure, the tendency of the zinc to volatilize is lessened and the melting loss is lowered. While the pressure on the interior of the furnaces during melting, with the charging door closed, is not very great, it is sufficient to lessen the volatilization of zinc in the metal being melted. Melters have frequently noticed that if the pouring spout of the furnace is slightly enlarged their melting losses are greater.

In a closed system, with equilibrium between melt and vapor, increase of pressure would of course drive back some of the vapor into the melt.[b] But the furnace must have some vent; hence it is not a closed system, and the problem is the effect of increase of pressure in the vapor phase on the rate of volatilization of zinc.

Stefan,[c] quoted by Ewan [d] and Mellor,[e] gives a formula for the relation between the speed of volatilization of a liquid in an inert gas with the partial pressure of the gas, the formula and derivation being as follows:

$$v = c \log \frac{P}{P - p_1} \text{ [f]}$$

in which—
v=speed of volatilization
c=a constant
P=pressure of gas and pressure of vapor
p_1=partial pressure of vapor

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[a] A letter to Mr. Longmuir requesting information on these details was unanswered.

[b] Compare with editorial reply to question regarding oxidation difficulties: Foundry, vol. 41, 1913, p. 120.

[c] Stefan, J., Sitzungsber. d. k. Akad. d. Wiss. zu Wien, vol. 68, 1878, p. 38.

[d] Ewan, I., Über die Oxidationsgeschwindigkeit von Phosphor, Schwefelund Aldehyd: Zeitschr. phys. Chem., vol. 16, 1895, p. 319.

[e] Mellor, J. W., Chemical statics and dynamics, 1904, p. 310.

[f] The logarithm is the natural, not the Briggsian logarithm

Let p_2 = pressure of gas.

Then $P = p_1 + p_2$

and
$$v = c \log \left(\frac{p_1 + p_2}{p_2}\right).$$
$$v = c \log \left(\frac{p_1}{p_2} + 1\right).$$

From the above it will be seen that the rate of volatilization will decrease as the pressure of the inert gas increases, other conditions remaining the same.

No data are available on the value of c, nor of p_1 or p_2 for the case in hand. However, in order to get some idea of the magnitude of the effect, it might be assumed that at a pouring temperature of 1,160° C. for an alloy consisting of 80 parts of copper and 20 parts of zinc, under equilibrium, the partial pressure of the zinc vapor will be 0.8 atmosphere. However, equilibrium is by no means reached, both because the gases are not fully saturated with zinc and because of the probable slowness of diffusion from the zinc-rich body of the melt into the zinc-poor surface. Were equilibrium established as to all the gases passing through the furnace, practically all the zinc would be lost.

Let it be assumed, then, that the partial pressure of zinc vapor is 0.05 atmosphere under the conditions in the furnace. With that assumption, the ratio of the rates of volatilization of zinc with increase in the pressure of the waste gases passing through the furnace from 1 atmosphere to 1.5 could be calculated as follows:

$$\frac{V_0}{V_1} = \frac{c \log \left(\frac{0.05}{1} + 1\right)}{c \log \left(\frac{0.05}{1.5} + 1\right)}$$

$$\frac{V_0}{V_1} = \frac{\log 1.05}{\log 1.033} = \frac{.04879}{.03278}, \text{ or a ratio of } 1:0.67.$$

A lesser increase in the gas pressure will of course result in a lesser saving of zinc. As the partial pressure of zinc vapor increases, the ratio of decrease of rate of loss of zinc to increase in pressure of waste gases increases; thus, the higher the percentage of zinc in the alloy, the greater the relative saving resultant on increase of the pressure of inert gas.

Hence it would appear that the improvement shown practically by increase of pressure in this type of furnace is in agreement with the theory.

The principle is of course applicable to all types, but the open-flame furnace is more easily closed so that an appreciable pressure can be maintained than are other types of fuel furnaces.

It should perhaps be pointed out that the increased pressure referred to above is that in the melting chamber over the metal, not that on the air supply to the burner, as high-air pressure on the burner appears to be detrimental, because it increases the velocity of

the gases and also renders the maintenance of a reducing flame more difficult. The increased pressure in the furnace chamber should be obtained by reducing the size of the opening at the pouring spout by having the burners fit tightly into the furnace and by keeping the charging door closed as much as possible.

VELOCITY OF FURNACE GASES.

It should be remembered that the evil effect of increase of the velocity of the gases passing over the metal is doubtless greater than the good effect of increase of pressure, so that pressure should not be sought at the expense of much increase of velocity. The gases do not become saturated with zinc vapor, but are continually taking it up. The less zinc vapor already in the gases the faster it is taken up. Hence, if the gases are passing through the furnace at a high speed, volatilization of zinc is increased, just as the wash hanging on the clothesline dries more quickly on a clear, windy day when the humidity is low, than they do on a still, damp day. For each fuel there is a lower limit to the speed with which the gases may travel through the furnace, as each fuel, in developing enough heat units to get the heat out at a given speed, must develop a certain volume of gases, and this must pass out. Hence proper gas velocity is inseparably connected with the volume of products of combustion produced from the various fuels.

Were the speed with which a given quantity of metal can be melted with various fuels and the volume of waste gases produced the same in all cases, the furnace design that would give the lowest zinc loss would be the one in which the gases moved the slowest. Again, too, a rapid rate of passage of hot gases through the furnace affords too short a time for them to give up their heat to the metal, resulting in slow melting and low fuel efficiency, more of the heat being carried out with the waste gases than is the case with a lower gas velocity.

De Heen[a] has found that on passing a gas current over a liquid surface the speed of evaporation increases with increase in temperature more rapidly than does the vapor pressure of the liquid. The amount of liquid evaporated was found to increase with increasing velocity of the gas passed over it, the relation between weight of liquid evaporated and velocity being expressed by the equation

$$H=\frac{S}{\sqrt{V}}$$

where H is a constant, S is the weight of liquid evaporated, and V is the speed of the gas current.

It is probable that molten metals follow the same general laws in regard to speed of vaporization as do liquids.

[a] De Heen, M., La ritesse de vaporisation des liquides: Jour. chem. phys., vol. 11, 1913, p. 205; chem. abstr., vol. 7, 1913, p. 3438.

VOLUME OF FLUE GASES FROM VARIOUS FUELS.

The main variables affecting the loss of zinc in melting brass that are under any control by varying the type of furnace or the fuel used are the speed of melting—that is, the time given for volatilization—the velocity with which the flue gases pass over the surface of the metal (rapidity with which gases unsaturated with zinc vapor are brought to the metal), and the volume of these gases per unit of metal melted for different fuels. With a given speed of melting, the greater the volume of the gases the greater the velocity with which they must pass over the metal; hence, with a given melting speed, the fuels giving the greater volume of flue gases per unit of metal melted give a greater tendency to zinc loss from both the velocity and the volume factors. About 144 cubic feet of air is necessary for complete combusiton of 1 pound of pure carbon, with no air excess (theoretical volume required), the volume of air being figured for the standard conditions of a temperature of 0°C. and a pressure of 760 mm. If allowance be made for the average proportions of moisture and ash in ordinary coal and coke, the volumes of flue gases per pound of fuel become as follows: Coke 128 cubic feet, anthracite coal 120 cubic feet, bituminous coal 123 cubic feet. Lewes [a] gives for petroleum 172.9 cubic feet, and Carpenter and Diederichs [b] give 182.1 cubic feet. If the average, 177.5, be taken, and if the weight of a gallon of oil be considered as 7¼ pounds, 1 gallon of oil would take nearly 1,300 cubic feet.

Gill [c] gives the volume of air theoretically needed for the combustion of 1 cubic foot of natural gas as 9.8 cubic feet; of city gas as 5.65 cubic feet, and of producer gas as 1.25 cubic feet.

Carpenter and Diederichs [d] state that 9 cubic feet of air is needed for natural gas; 5.25 cubic feet for city gas, and 1 to 1.15 cubic feet for producer gas. [e]

If the averages for natural and city gas, and Gill's figure for producer gas be taken, the figures are as follows: For natural gas, 9.4 cubic feet; for city gas, 5.45 cubic feet, and for producer gas 1.25 cubic feet. On this basis the volume of flue gases from the various fuels may be approximately computed.

For coke, the combustible part of which is practically all fixed carbon, and for anthracite coal, the volatile part of which (say 5 per cent) may be neglected as far as change in volume between air supply and flue gases goes, there is no noteworthy change in gas volume after combustion, the air and flue gas both being measured at standard conditions.

[a] Lewes, V. B., Liquid and gaseous fuels, 1907, p. 322.

[b] Carpenter, R. C., and Diederichs, H., Experimental engineering, 1912, p. 810.

[c] Gill, A. H., Gas-fuel analyses for engineers, 1912, p. 70.

[d] Carpenter, R. C., and Diederichs, H., loc. cit.

[e] The figures for producer gas are on richer gas than that represented in Reply 164, used for brass melting.

With bituminous coal there will be a slight increase in volume due to the presence of hydrocarbons, which may be figured at about 3 per cent, making the volume of flue gases about 127 cubic feet per pound of soft coal.

From figures given by Carpenter and Diederichs [a] the volume of the products of combustion from 1 gallon of oil would be about 1,400 cubic feet.

On natural gas, chiefly CH_4, the equation involved is—

$$CH_4+2O_2=CO_2+2H_2O$$

or the volume of the products of combustion is equal to that of gas plus air, or 10.4 cubic feet per cubic foot of natural gas.

On city gas of average composition, 1 cubic foot will correspond to about 6.3 cubic feet of flue gas.

On producer gas, owing to the diminution of volume in burning CO and H_2, 1 cubic foot corresponds to about 1.9 cubic feet of flue gas.

If, to get the relative order of the volumes of flue gases from different fuels, it be assumed that the combustion is both complete and without air excess, the figures are as follows:

	Cubic feet.
Coke, flue gases per pound	128
Anthracite coal, flue gases per pound	120
Bituminous coal, flue gases per pound	127
Fuel oil, flue gases per gallon	1,400
Natural gas, flue gases per cubic foot	10.4
City gas, flue gases per cubic foot	6.3
Producer gas, flue gases per cubic foot	1.9

From the data presented in the large table and in figure 20, it may be assumed that for the fuels represented fairly good fuel consumption per hundredweight of metal in the size of furnaces most used is as shown in the tabulation following:

Fuel-consumption figures for common fuels, per hundredweight of metal melted.

Kind of furnace:		
Natural-draft, pit, coke	pounds	45
Natural-draft, anthracite	do	38
Tilting, forced-draft, coke	do	25
Crucible, oil	gallons	2.75
Pit, tilting-crucible, oil	do	2.4
Open-flame, oil [b]	do	2.3
Reverberatory, oil	do	1.2

On soft-coal, reverberatory, and the various gas furnaces, the data are not sufficiently abundant nor concordant to allow fixing an average for good practice. Figures for the best, the poorest, and the average practice of all replies received are presented in the following table:

[a] Carpenter, R. C., and Diederichs, H., loc. cit.

[b] With 500-pound charge.

Fuel-consumption figures on soft coal (per hundredweight), reverberatory and various gas furnaces.

Kind of practice.	Kind of furnace.				
	Reverberatory, soft-coal.	Natural-gas, open-flame.	Natural-gas, crucible.	City-gas, crucible.	Producer-gas, crucible.
	Pounds.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
Best	18	200	231	256	[a] 3,500
Average	53	292	315	422	
Poorest	88	341	480	650	

[a] Only one report.

Calculated from the above, the volume of flue gases from each furnace under standard of 0° C, and 760 mm. pressure conditions, per hundredweight of metal melted is shown in the following tabulation:

Approximate volume of flue gases from different types of coal, coke, oil, and gas furnaces per hundredweight of metal melted.[a]

Kind of furnace:	Feet.
Pit, natural-draft, coke	5,800
Pit, natural-draft, anthracite	4,550
Tilting, forced-draft, coke	3,200
Pit, crucible, oil	3,800
Tilting, crucible, oil	3,500
Open-flame, oil	3,350
Reverberatory, oil	1,700
Reverberatory soft-coal (best)	2,300
Reverberatory, soft-coal (average)	6,950
Reverberatory, soft coal (poorest, on red brass)	11,000
Open-flame, natural gas best)	2,000
Open-flame, natural gas (average)	2,900
Open-flame, natural gas (poorest)	3,500
Crucible, natural gas (best)	2,300
Crucible, natural gas (average)	3,000
Crucible, natural gas (poorest)	4,700
Crucible, city gas (best)	1,550
Crucible, city gas (average)	2,400
Crucible, city gas (poorest)	4,000
Crucible, producer gas	6,200

As these figures are for the cold gases, the flue gases at furnace temperature will be expanded to much larger volumes, but those from the different fuels will still be in the ratio given.

If the effect of any small amount of unburned hydrocarbons be disregarded, the volume of flue gases will be greater than that computed if combustion is not complete, so that much CO is obtained, as one volume of oxygen used in combustion gives twice as much CO as CO_2. If an excess of air be used, the volume of the flue gases will of course be greater than that computed.

[a] In computing the volumes of flue gases from gaseous fuels, the figures for gas consumption reported have been assumed to be at the commercial standard conditions of 60° F. and 30 inches of mercury, and have been reduced to 0° C. and 760 mm. of mercury.

If the discordant data be disregarded for the reverberatory soft-coal furnace, it will be seen that coke or coal in natural-draft furnaces, under theoretical conditions of complete combustion and no air excess, involve the passage of more flue gases out of the furnace than any other fuel except producer gas; and that the forced-draft coke, and the oil, natural-gas, and city-gas furnaces have a considerable advantage on this point—an advantage, however, that is balanced or overbalanced by the greater velocity of the flue gases.

Inasmuch as producer gas has the disadvantages of possessing a low heating value and of giving a large volume of flue gas, it would appear that, although the gas is a cheap and suitable fuel for melting in crucible furnaces red brass, bronze, or other alloys low in zinc, in high-zinc alloys, such as yellow brass, in which the tendency of the zinc to volatilize is great, the probability of a high zinc loss in melting is great. In crucible furnaces, tightly covered, producer gas might perhaps be suitable for melting yellow brass, but it should seemingly be the last fuel to be used for open-flame or reverberatory melting if a low zinc loss is required, although it would be one ef the cheapest of fuels if cost of fuel only were considered.

It should be noted that in the discordant figures on the soft-coal reverberatory, the poorest figure reported was one on red brass, whereas the rest were on yellow brass or manganese bronze, so that in considering the flue-gas volume in regard to zinc loss, this high figure can hardly be regarded as typical.

As the best figure on city gas was reported by a gas company instead of directly by a foundry, it will be best to consider the average and poorest figures as more typical for that fuel.

In comparing oil and the various gaseous fuels in regard to zinc loss, it must be remembered that the volume of flue gases is only one of several factors.

In open-flame furnaces, Reardon [a] gives the results of a comparative test of oil and natural gas in open-flame furnaces on metal containing 18 per cent of zinc. The quantity of metal melted in each test was 4,550 pounds. The consumption of natural gas was only 143.5 cubic feet per hundredweight, whereas the oil consumption was 2.37 gallons per hundredweight—results that would amount to only 1,490 cubic feet of flue gases for natural gas as against 3,320 cubic feet for oil. The loss of metal with natural gas was, however, 2.69 per cent in comparison with 1.13 per cent with oil.

However, with the gas-fired furnace, 9 hours 54 minutes was required to melt 4,550 pounds, whereas with the oil furnace the same quantity was melted in 5 hours 52 minutes, the time with gas being one and two-thirds greater than with oil. Reply 104 [b] states that natural gas

[a] Reardon, W. J., The manufacture of high-copper castings: Metal Ind., vol. 8, 1910, p. 212.
[b] See p. 98.

has been discarded in favor of oil in open-flame furnaces in another foundry melting metal of about the same composition as was used in the test reported.

The reason for the greater speed of the oil furnace and its consequent lower melting loss is that oil is what might be called a more concentrated fuel than even natural gas; that is, with a suitable burner it is possible to burn the oil with a short enough flame to confine the combustion inside the furnace and yet to develop enough heat to melt a charge of metal in a shorter time than will be taken by natural gas to develop the same heat.

In other foundries, the one represented by reply 15 for instance, situated in natural-gas regions, where natural gas is regularly used in crucible furnaces, oil is regularly used in the open-flame furnaces. Reply 31 gives data on both open-flame, oil, and natural-gas furnaces, but gas is used in only one furnace, whereas oil is used in a dozen or more.

As, on account of the speed factor, natural gas proves less satisfactory in open-flame furnaces than oil, it follows that city gas or producer gas will be still less satisfactory, as they are both lower in heat units per cubic foot than natural gas, and both give larger volumes of flue gases than does natural gas.

In one foundry visited occasional melts of copper are made in an open-flame furnace. It had been found necessary to raise the pressure of the gas by a "booster" in order to obtain any satisfactory melting speed. Figures on gas consumption and melting loss were not available.

HIGH-PRESSURE GAS.

Onslow [a] advocates the use of city gas at a pressure of about 6 pounds per square inch for melting metal.

Goodenough [b] states that high-pressure gas, at a main pressure of about 15 pounds per square inch, is largely employed in Birmingham, England, for melting metal.

A furnace taking gas at 7 to 12 (average) pounds pressure is now on the English market.[c]

Smith[d] gives the following comparative figures regarding cost of melting brass in high-pressure gas furnaces and coke furnaces.

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[a] Onslow, A. W., Application of high-pressure gas to furnace uses: Jour. Soc. Chem. Ind., vol. 29, 1910, p. 395; abstracted in Jour. Inst. Met., vol. 3, 1910, p. 292; High-pressure gas for manufacturing purposes: Gas World, vol. 56, 1912, p. 822; Chem. Abst., vol. 6, 1912, pp. 2515, 3004.

[b] Goodenough, F. W., High-pressure gas lighting in Great Britain: Am. Jour. Gas Light., vol. 97, 1912, p. 227.

[c] Editorial, High-pressure gas furnace: Engineering (London), vol. 94, 1913, p. 531.

[d] Smith, E. W., Application of high-pressure gas for melting metals: Am. Jour. Gas Light., vol. 96, 1911, p. 699; Abstracted Jour. Soc. Chem. Ind., vol. 30, 1911, p. 1455.

Comparative cost per hundredweight of melting brass in high-pressure gas furnaces and in coke furnaces.

Item.	Gas furnace.	Coke furnace.
	d.	*s. d.*
Cost of pots	4	0 5
Cost of metal lost	10¼	1 4½
Cost of fuel lost	7½	4½

COVERS AND FLUXES.

Zinc loss should be considerably diminished by covering the metal with either a solid crucible cover or a molten flux. However, the solid cover is almost never used, only two firms having been found that use it, one melting manganese bronze in pit coke furnaces and the other yellow brass in tilting, crucible, oil furnaces. It has been stated by Corse [a] that the use of a crucible cover decreases the speed of melting by a quarter to a third.

A variety of fluxes is used in refining emery grindings or dirty borings;[b] those most used in the melting of clean metal are common salt, with or without the addition of silica, sand, and broken glass. A layer of crushed charcoal is almost invariably used on the surface of the metal, whether or not a cover of molten salt or molten glass is used. As fine charcoal is readily blown out of an open-flame furnace, large pieces of charcoal, slabs of wood, or crushed coal are often used. Jones [c] recommends a flux consisting of 1 part fluorspar to 3 parts of lime, together with some hard coal. Anhydrous boric oxide and charcoal form a cover that is described as promising by several firms, although such a cover has not so far found wide use.

It should be remembered that most molten fluxes or covers attack the crucible, or the furnace lining in a furnace not using a crucible, so that this disadvantage must be balanced against their advantages.

Although the fluxes are used mainly for the purpose of fluxing the metallic oxides, they serve also as a cover, and thus decrease the volatilization of zinc. When a pot of yellow brass covered with the usual salt and charcoal is pulled from the furnace at proper pouring temperature, it gives off zinc vapor, which burns as it strikes the air, forming a thin white fume of zinc oxide. As soon as the pot has been skimmed the zinc oxide rolls up in thick clouds. It seems likely that the almost universal use of a salt cover in rolling-mill melting, and its

[a] Corse, W. M., In discussion, Trans. Am. Inst. Metals, vol. 6, 1912, p. 198.

[b] Krom, L. J., Fluxes from the viewpoint of the metallurgist: Metal Ind., vol. 8, 1910, p. 203; Sperry, E. S., Fluxes as applied to the brass foundry: Trans. Am. Brass Founders' Assn., vol. 4, 1910, p. 67; Use of salt in melting copper alloys: Brass World, vol. 8, 1912, p. 67; Primrose, H. S., A discussion of modern brass founding: The Foundry, vol. 40, 1912, p. 366; Ott, C. E., The opportunities of a metallurgical chemist; Metal Ind., vol. 8, 1910, p. 501.

[c] Jones, J. L., Answer to question on melting: Metal Ind., vol. 11, 1913, p. 437; vol. 12, 1914, p. 81.

much less common use in sand-casting shops, may partly account for the generally greater zinc loss from yellow brass in such shops than in the rolling mills, because the pouring temperature in the rolling mills is as high or higher than that in the plants making sand castings of ordinary thickness.

Bassett,[a] on the other hand, states that the use of chlorides as fluxes in melting brass promotes the volatilization of zinc, and cites the almost complete dezincification of thin brass sheets (2.5 mm. thick) annealed at 650° C. for an hour, with driftwood as fuel. Bassett's test shows that flue gases containing the vapor of a chloride such as sodium chloride will aid the volatilization of zinc, but the actual conditions of melting under a molten cover are not strictly comparable to the conditions in the test cited. In several of the plants visited molten covers of salt or glass were used, and the users were strongly of the opinion that such covers reduced the zinc loss.[b]

A molten cover should also tend to make oxidation or other chemical action by the flue gases less rapid, and to prevent the occlusion or solution of gases.

GASES ABSORBED IN MELTING METAL.

The question of the chemical action of various gases and their solution in the alloys melted is one on which little authoritative information is at hand. The gases to be considered are mainly nitrogen, carbon dioxide, carbon monoxide, oxygen, sulphur dioxide, and water vapor. In the melting of the constituents of an alloy a gas may enter into chemical combination with the copper or the other metals in the alloy, forming oxides of those metals, or may be occluded in the alloy.

Occlusion is most strikingly illustrated in the melting of silver, which, at 1020° C., can absorb about twenty times its own volume of oxygen,[c] the solubility increasing with the temperature. On freezing, silver that has absorbed oxygen gives it up, and it is to this characteristic that the well-known "spitting" of silver on freezing is due. Platinum and palladium, in the solid state, can occlude a large proportion of hydrogen, the volume occluded decreasing as the temperature is raised.[d]

As the absorption of gases by a molten metal is a matter of solution rather than of occlusion,[e] an increase in temperature increases the gas absorption. As the metal freezes, the dissolved gases are liberated. If it freezes so rapidly that the gas bubbles can not pass up through

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[a] Bassett, W. H., Zinc losses: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 164; Metal Ind., vol. 10, 1912, p. 2[illegible].

[b] See Replies 21, 28, 30, 91, 151 in the large table.

[c] Donnan, F. G., and Shaw, T. W. A., Solubility of oxygen in molten silver: Jour. Soc. Chem. Ind. vol. 29, 1910, p. 987.

[d] Findlay, A., The phase rule, 1904, p. 177.

[e] However, after the metal has solidified, the gases that are retained are usually said to be occluded.

the metal before it has set, blowholes are formed. Other causes of blowholes are the presence of air, trapped in pouring, and of gases evolved by the mold or cores when the hot metal strikes them, but dissolved gas is unquestionably one of the main causes of porosity and of blowholes.

Shepherd and Upton [a] discuss this matter as follows:

A casting trouble that no variation of mold can rectify is the pinholing, or sponginess, which is due to gases occluded in the molten metal. Molten copper and molten bronzes down to 85 per cent copper have the power of absorbing gases. When freezing begins these gases are set free, with the result that the mass of the casting is filled with tiny bubbles of sizes from a pinpoint to a pinhead. The only way to avoid this is by proper treatment of the melt in the furnace. The absorption of gases is roughly proportional to the time the metal is held molten. Hence the furnace was run hot and the time of melting kept as short as possible. The metal must be gotten hot, for if poured too cold it is practically certain to trap air bubbles. It was found also that the occluded gas was much worse in the top of the melt.

Sperry [b] says:

Blowholes in sand castings almost entirely come from the gases generated by the combustion of the fuel during the melting and becoming absorbed during the melting. As the metal cools in the mold, these gases are expelled, forming blowholes. Blowholes and pinholes are the same and are produced by gas absorption. One is simply larger than the other.

The reason why, with the same manner of melting and the same metal, blowholes will be present in one casting and not in another is in the method of melting. All fuels used in the brass foundry at the present time contain sulphur, and, of course, various gases, such as carbon monoxide, carbon dioxide, hydrogen, are generated by the combustion of the fuel. It is the sulphur that is a very common cause of the trouble, although the other gases play an important part. When the metal melts, it absorbs these gases, and then, after it has been cast in the sand mold, they are expelled, and blowholes form.

In melting, therefore, the metal should be protected against these gases. A common and excellent method is to keep the surface of the metal covered with charcoal.

Sperry also states [c] that slow melting favors the absorption of gas and the formation of oxide, whereas too rapid melting overheats the projecting edges of the ingots, excessive overheating of solid metal causing gas absorption and the formation of blowholes in the castings.

Carpenter and Edwards [d] state that one main cause of porosity and blowholes is that "when melted, the alloy dissolves gas, the amount increasing with the rise of the temperature and the duration of melting. The composition (of the gas) depends on the fuel used and the way it is applied. But no alloy melted under practical conditions escapes contamination by gas."

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[a] Shepherd, E. S., and Upton, G. B., The tensile strength of the copper-tin alloys: Jour. Phys. Chem., vol. 9, 1905, p. 453.

[b] Sperry, E. S., Blowholes in valve castings: Brass World, vol. 9, 1913, p. 51.

[c] Sperry, E. S., Speed of melting of copper and brass: Brass World, vol. 4, 1908, p. 253; Chem. Abs., vol. 2, 1908, p. 2926.

[d] Carpenter, H. C. H., and Edwards, C. A., Production of castings to withstand high pressures: Engineering (London), vol. 90, 1910, p. 871.

Johnson[a] discusses this feature as follows:

The regulation of the quantity of oxygen in copper is the keynote of all copper refining. It is the presence of a well-defined proportion of oxygen in the form of cuprous oxide, forming a copper-cuprous oxide eutectic, which enables copper to be cast free from blowholes. It seems that when oxygen is present, other gases are less soluble in molten copper; when oxygen is absent, or is present in insufficient quantity, the copper dissolves other gases, such as hydrogen and carbon monoxide, which are insoluble in the copper when solid, and, being rejected during the process of solidification, cause internal porosity and external ridges or excrescences.

Johnson[b] advances the theory that "set" copper—copper with an excess of cuprous oxide, an ingot of which freezes with a concave upper surface—contains no gas; that "tough-pitch" copper—that containing a little oxide, which sets with a level surface—contains just enough gas so that the buoyant tendency of the gas in minute cavities just counteracts the natural tendency of the ingot to "pipe" or set with a concave surface, and that in "over-pitch" copper—copper containing little or no oxide, which freezes with a concave surface—there is enough gas so that the buoyant tendency of the gas overbalances the tendency to "pipe." He states that a fractured surface of "set" copper is entirely free from gas cavities; that a fractured surface of "tough-pitch" metal contains minute gas cavities, uniform in size and distribution, but so small that they do not materially affect the mechanical properties of the metal, as they are welded together in rolling; and that in the case of "over-pitch" metal the gas cavities are more numerous, larger, and more variable in size than in the case of "tough-pitch" metal, the larger cavities occurring at the top of the ingot.

Shepherd and Upton[c] state that their worst trouble from gas inclusions in the copper-tin alloys was with compositions containing more than 90 per cent of copper, and that bronzes, with less than 85 per cent of copper, do not appear to dissolve, or if dissolved, to retain gases.

Lohr[d] had his worst trouble from gas inclusions in copper-zinc alloys with copper percentages of from 65 to 80 per cent, little trouble being experienced with a percentage above 80 per cent. He had more trouble when illuminating gas was led over the melt than when a cover of charcoal and molten salt was used.

Curry and Woods[e] passed illuminating gas over the melt when working with the copper-aluminum alloys, an arrangement that they found effective in excluding oxygen, so that they had little trouble from included gas.

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[a] Johnson, F., Effect of silver, bismuth, and aluminum upon the mechanical properties of "Tough-pitch" copper containing arsenic: Jour. Inst. Metals, vol. 4, 1910, p. 163.

[b] Johnson, F., op. cit., p. 206.

[c] Shepherd, E. S., and Upton, G. B., op. cit., p. 454.

[d] Lohr, J. M., The tensile strength of the copper-zinc alloys: Jour. Phys. Chem., vol. 17, 1913, p. 20.

[e] Curry, B. E., and Woods, S. H., The tensile strengths of the copper-aluminum alloys: Jour. Phys. Chem., vol. 11, 1907, p. 464.

Primrose[a] says:

The time of a melt should be kept as short as possible, as prolonged "stewing" only tends to increase the absorption of gas, which caused blowholes when the metal solidifies.

Weintraub says: [b]

The cause of the difficulty of producing sound, pure-copper castings has been sufficiently well understood for a long time. Molten copper has the property of dissolving gases and of setting a part of these gases free on cooling. This produces pinholes and even big cavities. The casting obtained is therefore mechanically unsound and has naturally a low electrical conductivity.

The elimination of these dissolved gases presents but little difficulty. It is sufficient to add one of the well-known deoxidizers, such as zinc, magnesium, phosphorus, etc., in small quantities to bind the oxygen or the gaseous oxygen compound chemically. The electrical conductivity of the copper thus produced is, however, as a rule, low. The amount of the gaseous oxygen compound dissolved in copper during the process of melting is a variable quantity and is distributed throughout the whole mass.

Guillemin and Delachanal[c] state that brasses contain from 1 to 30 times their own volume of gases, which consist of H_2, CO_2, and CO, much of the gases being H_2. These gases were given up only when the alloys were heated to the melting point under reduced pressure. In pieces not showing blowholes the gas was mainly H_2, whereas in those that did contain blowholes, the H_2 was accompanied by CO and a little CO_2. The H_2 did not seem to injure the physical properties of the pieces not showing blowholes.

Guichard[d] finds, however, that the gas retained by commercial copper is mainly CO_2.

Reply 203 states that the gases retained by bronze are mainly nitrogen.

Reply 189 states that the writer has found CO_2 and SO_2 retained in copper and gun metal, but no sulphide sulphur, and that there is no trouble in yellow brass from the taking up of SO_2.

Reply 173 states that in melting yellow brass in a soft-coal reverberatory no trouble has been met from the sulphur in the coal.

Reply 180, on a similar furnace, says that no trouble has been met from this cause either in manganese bronze or gun metal.

Sperry[e] states that sulphur in copper causes blowholes, referring to sulphur present in the copper, not to SO_2 from the fuel, although he ascribes blowholes to the presence of SO_2 also.

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[a] Primrose, H. S., A discussion of modern brass founding: Foundry, vol. 40, 1912, p. 366.

[b] Weintraub, E., Cast copper of high electrical conductivity: Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 207.

[c] Guillemin, G., and Delachanal, B., Occlusion of gases contained in certain copper alloys: Metal Ind., vol. 9, 1911, p. 36; Compt. Rend., vol. 151, 1910, p. 881; abstracted in Jour. Inst. Metals, vol. 4, 1910, p. 311.

[d] Guichard, M., Sur l'extraction des gaz du cuivre par la chaleur: Bull. Soc. chem., 4th ser., vol. 11, 1912, p. 50; abstracted in Jour. Inst. Metals, vol. 7, 1912, p. 284.

[e] Sperry, E. S., The effect of sulphur in copper: Brass World, vol. 9, 1913, pp. 52, 57. See also editorial, Sulphur in alloys: Foundry, vol. 42, 1914, p. 74.

On the other hand, the chemist of a well-known firm manufacturing valves stated that in his experience some Japanese copper had contained considerable sulphur, and that its only effect was to give the castings a dark color, without altering the physical properties of the alloy or giving any foundry troubles.

Sieverts [a] finds that N_2, CO_2, and CO are not appreciably dissolved by copper, but that SO_2 is rather soluble in it, 100 grams dissolving about 0.5 gram of SO_2 at 1,200° C., 0.7 gram at 1,300° C., and 0.95 gram at 1,500° C., the SO_2 being pure and under a pressure of 1 atmosphere.

He states also that besides the solution there is some chemical action, the equation $Cu_2S + 2Cu_2O = SO_2 + 6Cu$ being reversible.

Hoffman, Hayden, and Hallowell [b] also state that Cu_2O, Cu_2S, and SO_2 can be present together in "tough-pitch" copper. These authors quote Hampe,[c] who found that SO_2, H_2, and CO were dissolved by copper, and that CO_2 was not soluble. He was able to drive out the other gases by heating in CO_2.

They also quote Stahl as finding that 0.025 per cent of lead added to copper greatly decreased its ability to absorb gases and made copper tough enough to stand hammering, rolling, and drawing, although without the lead the copper was porous and would not stand mechanical work.

Heyn and Bauer [d] state that the reaction $Cu_2S + 2Cu_2O = 6Cu + SO_2$ is reversible, stating that under conditions such that the Cu_2O can exist the reaction at 900° to 1,100° C. goes to the right; that is, the copper is not attacked by SO_2; but that if conditions are such that the Cu_2O is not formed or is oxidized (as by charcoal) as fast as formed, then SO_2 will attack the copper and form the sulphide.

Peters [e] states that in melting and refining cathode copper in a soft-coal reverberatory SO_2 will be absorbed as long as it is being evolved in the fire box, and that its influence is diminished by dipping the cathodes in milk of lime before the metal is charged into the furnace.

Schenck and Hempelmann [f] have studied the reaction $Cu_2S + 2Cu_2O = 6Cu + SO_2$ up to 730° C. and give one equilibrium diagram, but report no work on molten copper.

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[a] Sieverts, A., and Krumbhaar, W., Solubility of gases in metals and alloys: Ber. Deutsch. chem. Gesell., vol. 43, 1910, p. 1893; abstracted in Jour. Inst. Metals, vol. 3, 1910, p. 288; Zeitschr. phys. Chem., vol. 82, 1913, p. 257. See also Stubbs, C. M., Action of sulphur dioxide on copper at high temperatures: Jour. Chem. Soc., vol. 103, 1913, p. 1445.

[b] Hoffman, H. B., Hayden, H. O., and Hallowell, R., A study in refining and overpoling electrolytic copper: Trans. Am. Inst. Min. Eng., vol. 38, 1907, p. 171.

[c] Hampe, W., Beiträge zu der Metallurgie des Kupfers: Zeitschr. Berg-Hütten und Salinen-wesen in Preussen., vol. 21, 1873, p. 274.

[d] Heyn, E., and Bauer, O., Kupfer und Schwefel: Metallurgie, vol. 3, 1906, p. 73.

[e] Peters, E. O., Practice of copper smelting, 1911, p. 566.

[f] Schenck, R., and Hempelmann, E., Experimentelle und theoretische Studien über die Grundlagen der Kupferhüttenprozesse: Metall und Erz., vol. 10, 1913, p. 283.

Hüser[a] says that during the oxidizing smelting process Cu absorbs chiefly O_2 from the furnace gases, but also some SO_2 and H_2, whereas H_2, CO_2, and CO are not dissolved. When the copper solidifies, part of the H_2 forms a solid solution and the S and O_2 separate as Cu_2O and Cu_2S. As the metal freezes, solidification starting at the walls of the mold, the eutectics formed by Cu_2O and Cu and by Cu_2S and Cu are forced to the center, which is thus enriched in Cu_2O and Cu_2S. These compounds then react, forming Cu and SO_2, as is shown by the rising of the metal, and by the Cu becoming porous.

Hüser further states that the SO_2 dissolved in Cu is mechanically removed by poling.

Hofman[b] says: "The statement of the insolubility of CO in Cu will be doubted by copper refiners."

Clamer[c] makes the following statement:

> I am firmly of the opinion that many of our failures which we have ascribed to oxygen are, in reality, due to sulphur. I have made some investigations along these lines, and have found that in the most careful crucible melting in coke-fired furnaces the metal will take up from 0. 02 to 0.05 per cent sulphur. Copper has the greatest affinity for sulphur of any of our metals, outside of manganese, and naturally it tends to absorb it if brought into contact with sulphur-carrying gases. Sulphur accumulates each time the metal is melted, and this accounts for the dark skin on rerun castings, as compared with those of first-melt metal.

The question of the effect of SO_2 in the flue gases is of consequence, because if the effect is harmful, the utility of soft coal in reverberatory or semiproducer furnaces, of producer gas not well purified from sulphur,[d] or of fuel oil high in sulphur[e] would be diminished.

The evidence is contradictory. However, it is certain, in view of the universal practice of using charcoal (which tends to give an atmosphere high in CO and low in O_2, with, of course, an abundance of N_2 directly over metal to be melted) that CO and N_2 stand out as the least harmful. As to CO_2 and H_2 the evidence is contradictory. Oxygen certainly, and SO_2 possibly, are harmful, both through chemical action and through being held in solution by the melt, to be subsequently given out to form blowholes as the metal "freezes." That the charcoal cover does not completely keep out gases, even oxygen, is shown by the fact that copper melted under charcoal needs a deoxidizer, such as silicon, phorphorus, titanium, or boron suboxide, in order to free it completely from oxygen.

Aside from the above-mentioned chemical methods of degasification, which are usually aimed solely at the elimination of oxygen,

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[a] Hüser, F., Kupferraffination mit Magnesium: Metall und Erz., vol. 10, 1913, p. 479; Met. Chem. Eng., vol. 11, 1913, p. 518.

[b] Hofman, H. O., General metallurgy, 1913, p. 20.

[c] Clamer, G. H., Electric melting of copper and brass: Trans. Am. Inst. Metals, vol. 6, 1912, p. 130.

[d] Fernald, R. H., and Smith, C. D., Résumé of producer-gas investigations: Bull. 13, Bureau of Mines, 1911, p. 27.

[e] Allen, I. C., and Jacobs, W. A., Physical and chemical properties of the petroleums of the San Joaquin Valley of California: Bull. 19, Bureau of Mines, 1912, pp. 27, 28.

two methods of getting rid of dissolved gases are used. In the first method[a] the metal is poured while very hot, so that gas set free as the metal cools may escape before the metal sets; in the second[b] the metal is allowed to cool in the crucible or ladle to the lowest possible pouring temperature, thus releasing most of the gas before the metal is poured. It would be better to melt the metal without introducing the gas, than to get the gas in and be forced to eliminate it. Just which alloys are the most susceptible to gases and just what gases are most harmful are still matters of speculation.

From the foregoing discussion it would appear easier to prevent molten metal from absorbing gases in crucible furnaces than in open-flame or reverberatory furnaces; and it would appear that natural-draft furnaces, with a slow velocity of the gas passing over the metal, would probably give less trouble in this connection than would forced-draft furnaces, or oil or gas furnaces. In the replies represented in the large table, with accompanying notes, the frequent mention of poor results with forced-draft, coal or coke, oil or gas, and particularly open-flame oil furnaces, shows that such furnaces are more likely to give trouble from gas absorption than are the natural-draft coal or coke furnaces. On the other hand, the equally frequent mention of the successful use of all these types of furnaces for melting metal for castings, such as valves, in which any porosity is fatal, shows that these furnaces can be run without bad results from gas absorption.

On visits to plants in the course of the collection of the data herein compiled, the writer has seen difficult castings made from metal melted in open-flame oil furnaces that were certainly as good as could have been made in a natural-draft crucible coke or coal furnace. Pure cast copper and the aluminum alloys are as difficult to cast without porosity as any alloys known, yet in open-flame oil furnaces they are melted with absolutely satisfactory results.

In one plant the author saw castings that were made from an alloy of aluminum with 5 to 8 per cent of magnesium—one of the hardest compositions to cast without porosity. Blowholes or porosity will usually occur at the junction of the gate and the casting. Yet castings from this alloy melted in an open-flame oil furnace were absolutely sound at that point.

However, at the plant mentioned, as at others successfully using this type of furnace, every effort was made to run the furnaces with a strongly reducing flame. The matter of whether such furnaces are run under oxidizing or reducing conditions seems to make most

[a] Reardon, W. J., The manufacture of pure-copper castings: Metal Ind., vol. 8, 1910, p. 5.

[b] Carpenter, H. C. H., and Edwards, C. A., Production of castings to withstand high pressures: Engineering (London), vol. 90, 1910, p. 871.

of the difference between unsatisfactory and satisfactory performance. The writer was interested in noting in one well-run plant using both tilting oil-fired crucible furnaces and open-flame oil furnaces that the hoods over the open-flame furnaces were thickly sooted, showing that a strongly reducing flame was commonly used therein, whereas the hoods over the crucible furnaces were only slightly sooty, indicating that the flame used in them was not so strongly reducing.

It would appear that the flue gases from a furnace operating with a reducing flame are not so soluble in the metal as those from a furnace operating with an oxidizing flame.

Inasmuch as it is better to use a little more fuel, burning its carbon largely to CO instead of to CO_2, than it is to get a higher fuel efficiency through complete combustion, thereby burning the metal and filling it with gas and oxides, the aim of combustion in melting brass and bronze should be to burn completely the oxygen of the air supplied, rather than to burn completely the carbon of the fuel, as such combustion demands an excess of air. Thus, the proper methods of burning fuel in brass melting and in boiler practice are sharply differentiated.

Although any of the commercial types of furnaces can be so run as to give little or no trouble from dissolved gas, it would seem that, in order to make the proper operation of the furnace more "fool-proof," a suitable molten cover or flux should be distinctly advantageous in cutting down gas absorption. The use of such a cover deserves more attention than is being given it to-day by foundries making sand castings, and there is reason to believe that some more efficacious cover than molten salt may be found for rolling-mill work.

SPEED OF MELTING.

As gas absorption is proportional to the temperature and to the time the metal is held at a given (high) temperature, it is essential that, to minimize such absorption, melting be rapid, and that the metal be taken from the furnace the instant it has reached the desired temperature.

As loss of zinc is also proportional to the temperature and to the length of time the metal is held at a high temperature, rapid melting and prompt withdrawal of the metal are vital if the zinc loss is to be kept down.

This statement does not mean that melting two 50-pound heats in an hour is necessarily any better than melting one 100-pound heat in the same time, but it does mean that any procedure that reduces the time per hundredweight of melt, or increases the weight of metal

melted per hour, will tend to reduce the gas absorption and the zinc loss.

Fuel efficiency also demands rapid melting, and the rapid withdrawal of metal from the furnace. Roughly speaking, the first heat in the morning, on most furnaces, will require twice the time and twice the fuel that the last heat will. If the rate of heating is slow and few heats per day are made, the fuel used in heating the cold furnace to working temperature holds too great a proportion to the total fuel used throughout the day, and makes the fuel cost per hundredweight of metal melted higher than in a furnace using the same fuel but giving more rapid heating. Similarly, a fuel allowing great melting speed may from this fact alone have a real advantage over a fuel cheaper on a heat-unit basis, but not allowing a rapid rate of melting.

It also follows that tilting or tapping furnaces, which may be recharged the moment one heat is taken out, have an advantage over pit furnaces, which must either remain empty while the crucible is being taken away, the metal poured, and the crucible brought back, or else a cool crucible must be used. As allowing the crucible to cool very much between heats shortens its life and wastes the heat stored in it, the furnace is usually kept vacant till the crucible is brought back. In pit oil or gas furnaces the burner may be shut off or turned down while the crucible is out, but in pit coal or coke furnaces combustion of the fuel goes on whether the crucible is there or not.

Rapid melting means, also, for a given outlay for furnaces and for a given floor space, a lower overhead charge per hundredweight of metal than slow melting, and means, in general as well, a lower labor cost per hundredweight of melt.

It is thus worth while to consider what factors in the design of a furnace for any given fuel, what fuels, and what methods of operation make for the most rapid melting.

It is a general principle of furnace design, which holds good for all furnaces, whatever be the method of heating, that the greater the capacity of the furnace the less the loss of heat through radiation and conduction in the furnace walls.[a]

In this connection it is worthy of note[b] that the size of the reverberatory furnaces for copper smelting has steadily grown from one with a hearth area of 8 by 11 feet in 1800 to one with a hearth area of 19 by 120 feet in 1911.

Mathewson[c] gives the following table bearing on the relation of hearth area to tonnage:

[a] See Stansfield, A., The electric furnace, 1908, p. 35.

[b] See Mathewson, E. P., The development of the reverberatory furnace for smelting copper ores: Proc. 8th Int. Cong. App. Chem., vol. 3, 1912, p. 113.

[c] Mathewson, E. P., loc. cit.

Relation of hearth area to tonnage produced.

Hearth area of furnace.	Metal melted per 24 hours.	Cupreous material per ton of coal.
Feet.	*Tons.*	*Tons.*
19 by 50	121.74	2.75
19 by 60	190.7	3.94
19 by 85	234.1	4.13
19 by 102	264.9	4.31
19 by 112	267.1	4.30
19 by 116	270.1	4.19

For a given volume of charge the smaller the area of the furnace walls the less the heat loss, other conditions being equal; that is, in the case of a crucible furnace a cylindrical furnace will lose less heat and will give a better fuel efficiency and a higher melting rate than a square one.

In the case of open-flame furnaces, the theory calls for a better performance from a spherical furnace than from a cylindrical, oval, or rectangular one.

In a crucible furnace, the larger the charge the better the fuel efficiency and the speed. Unfortunately, the larger the crucible the shorter its life, so that in pit furnaces a point is soon reached when the life of the crucible is so short that the crucible cost per hundredweight of metal melted becomes so great that it overbalances all other advantages of the large furnace. In tilting-crucible furnaces much larger sizes may be economically reached, but even with these the condition soon arises that the labor loss and danger from the breaking of one big crucible is so great that the risk can not be borne. Thus the open-flame and the reverberatory furnaces take the lead for economically melting large charges.

Again, the heat absorption by the metal, and hence the speed of melting, is greater if there is no crucible wall between the metal and the source of heat, so that crucible furnaces are again at a disadvantage.

In the open-flame or the reverberatory furnace the larger and shallower the hearth the greater the surface exposed per unit of volume and the shorter the distance through which the heat has to travel through the metal to reach all parts of the melt. Unfortunately, the greater the surface per unit volume the greater the loss of zinc and the danger of gas absorption or of oxidation, so that this factor prevents going to the use of an extremely shallow bath of metal.

In a crucible furnace the taller the crucible and the smaller its radius the greater the heating surface per unit volume and the shorter the path through the metal through which the heat must travel from the crucible wall. Thus the tilting-crucible furnace that

uses a tall, narrow crucible has a distinct advantage in fuel economy and melting speed over the pit furnace that uses a short, fat crucible with considerable bilge.

With external heating, as with crucibles, the sphere, to which pit crucibles more nearly approximate than do tilting crucibles, has less heating surface than the more nearly cylindrical tilting crucibles, and is therefore less desirable.

RELATION OF WEIGHT OF CHARGE TO MELTING SPEED.

The effect of the size of the furnace—that is, of the volume or weight of charge—may best be seen by plotting the data collected to show the

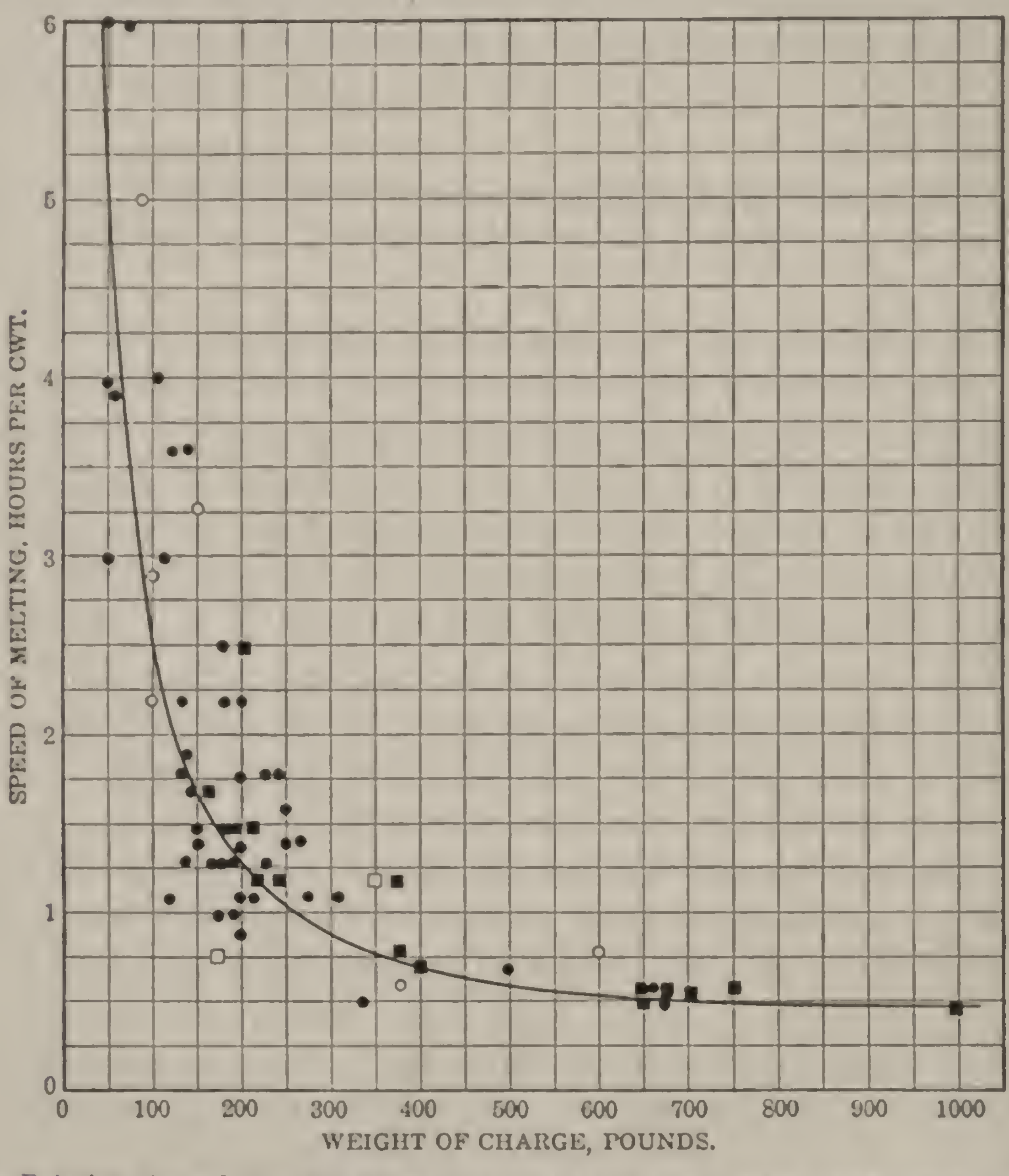


FIGURE 3.—Relation of speed of melting to weight of charge in natural-draft, coke furnaces. ● round, pit, natural-draft, coke furnace, melting low-zinc alloy (subdivision 1 of large table); ■ square, pit, natural-draft, coke furnace, melting low-zinc alloy (subdivision 2); ○ round, pit, natural-draft, coke furnace, melting high-zinc alloy (subdivision 3); □ square, pit, natural-draft, coke furnace, melting high-zinc alloy (subdivision 4).

relation between weight of charge and time per hundredweight of metal melted, which is done in figure 3. Operating conditions vary so that large individual variations are shown in most cases, but the data are sufficiently numerous for the shape of the curve to be well defined.

The data in the large tables, with the exception of those presented in subdivisions 21, 22, and 23, relating to pit oil furnaces with several crucibles in the same pit, have been plotted in figures 3 to 9, to show the relation between speed of melting and weight of charge. The scale of figure 9 is different from that used in figures 3 to 8.

Figure 3, covering natural-draft, pit, coke furnaces, shows that furnaces with a capacity of 150 to 250 pounds are the most common of this type, and that most of the square furnaces have a capacity of more than 350 pounds.

Figure 4, covering natural-draft pit, anthracite-coal furnaces, shows that this type is a rarity in sizes having a capacity of more than 275 pounds. In the figure, the plotting points for square furnaces with a capacity of about 200 pounds, which lie below the curve, represent rolling mills melting yellow brass, the comparatively greater speed being ascribable to the lower melting point of the alloy and to the fact that the metal is more likely to be taken from the furnace as soon as it is ready in rolling-mill practice than in sand-foundry practice, because there is no waiting for the molds to be put up.

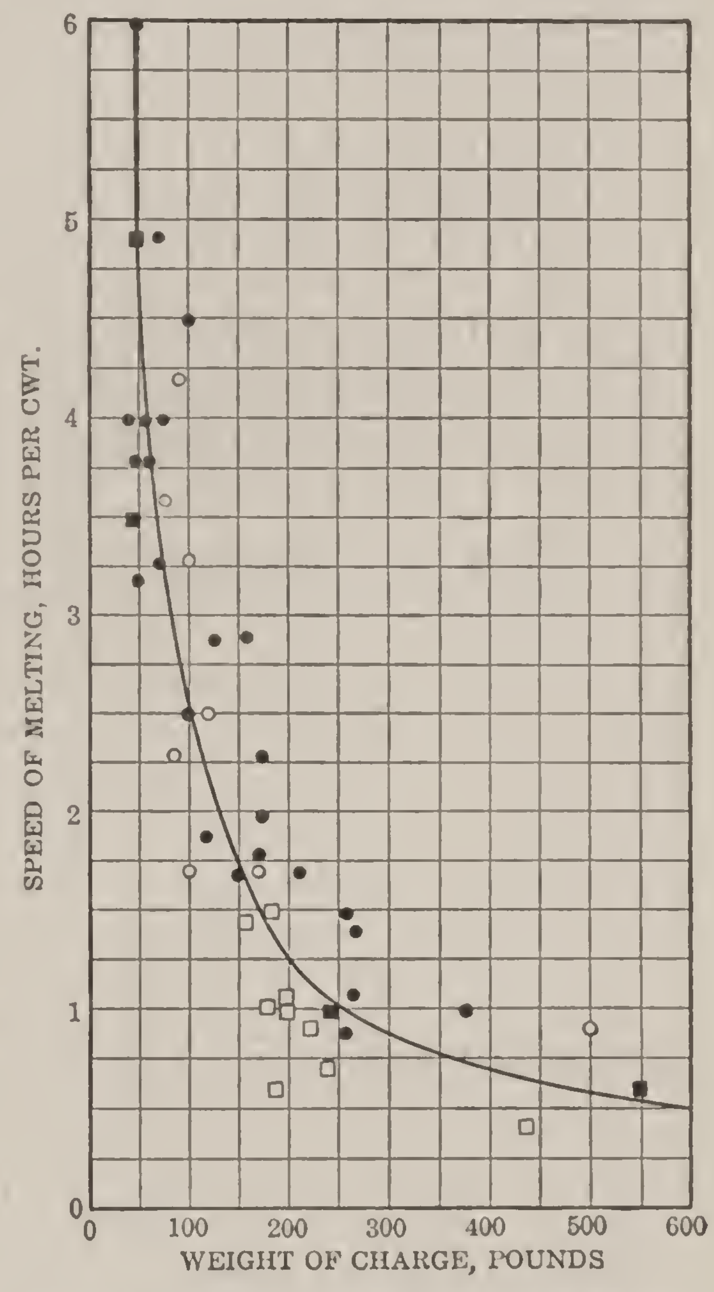


FIGURE 4.—Relation of speed of melting to weight of charge in natural-draft, coal furnaces. ● round, pit, natural-draft coal furnace, melting low-zinc alloy (subdivision 7 of large table); ■ square, pit, natural-draft coal furnace, melting low-zinc alloy (subdivision 8); ○ round, pit, natural-draft coal furnace, melting high-zinc alloy (subdivision 9); □ square, pit, natural-draft coal furnace, melting high-zinc alloy (subdivision 10).

The curves in figures 3 and 4 are identical; although coke is universally admitted to be capable of faster melting than coal under the same conditions in a natural-draft furnace, as the furnaces are run in practice, there appears to be no difference in the speed when the average is taken in both cases.

Figure 5 shows the speed of the forced-draft, coal or coke furnaces.

Figure 6 shows the speed of crucible oil furnaces, both pit and tilting. The capacity of the sizes mainly used ranges from 150 to 400 pounds. It will be seen that burners with high-pressure air give no better melting speed than those with low-pressure air.

Figure 7 shows the speed of crucible gas furnaces. Not enough data are available to fix the curve with certainty. The same curve used

in figure 6 for oil furnaces has been represented, and fits the data fairly well.

Figure 8, covering the open-flame furnaces, shows much less variation in speed of melting with the weight of charge than in the previous cases, and indicates that this type of furnace would be useful in melting charges smaller than those for which it is commonly used.

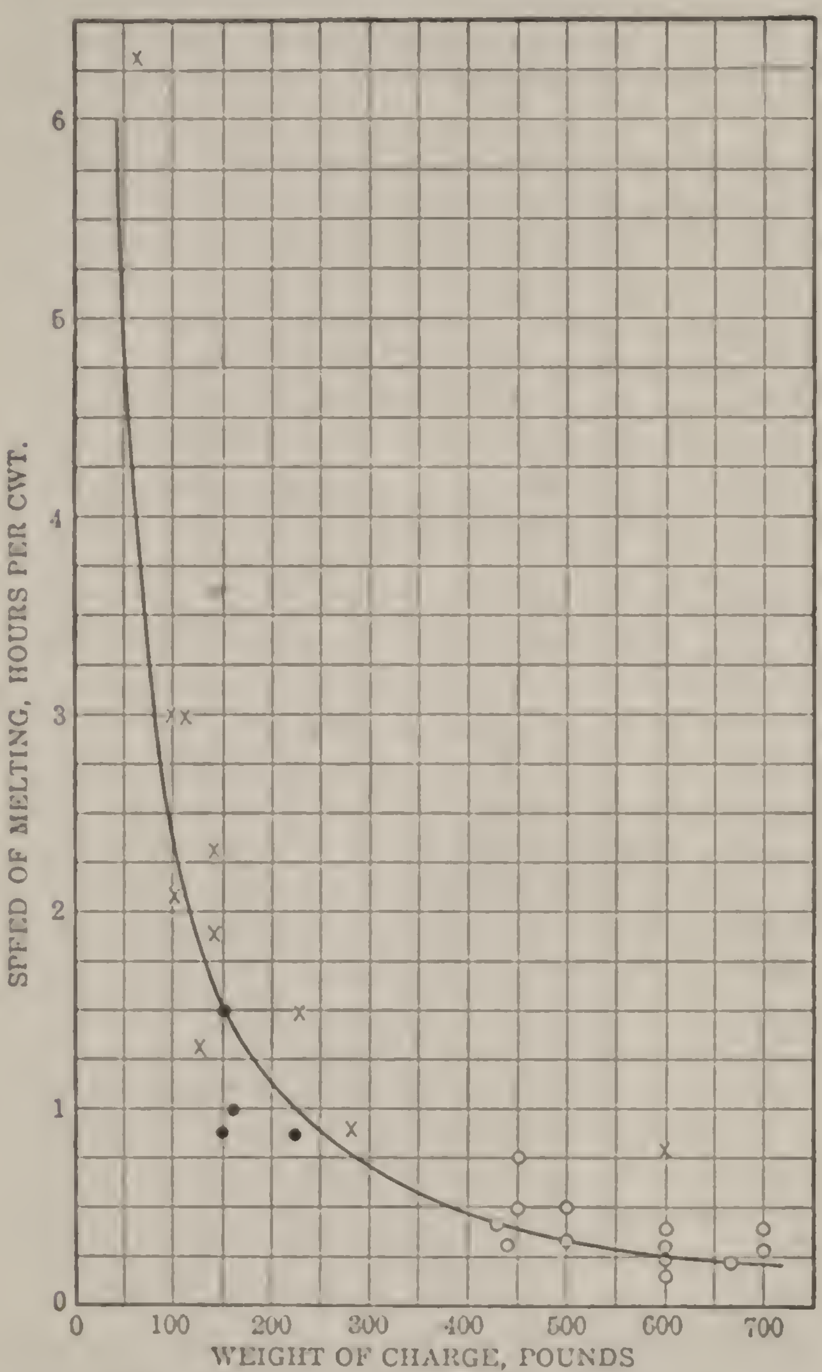


FIGURE 5.—Relation of speed of melting to weight of charge in forced-draft, coke or coal furnaces. ● pit, forced-draft, coke furnace (subdivisions 5 and 6 of large table); × pit, forced-draft, coal furnace (subdivisions 11 and 12); ○ tilting, forced-draft, coke furnace (subdivisions 13, 14, and 15).

Figure 9, covering reverberatory furnaces, has been drawn to a different scale than that used in figures 3 to 8, because of the large charges used.

In Figure 10 the curves of averages shown in figures 3 to 9 have been drawn to the same scale. It is seen that on natural-draft coal or coke furnaces there is a rapid improvement in speed as the capacity increases from 150 to 600 pounds; that the use of forced draft improves the speed greatly in furnaces with a capacity of 200 pounds up; that crucible oil or gas furnaces all along average a much better speed than natural-draft coke or coal furnaces, whereas they are more rapid than forced-draft coke furnaces with capacities up to about 450 pounds, but that for capacities greater than 450 pounds the forced-draft coke furnace is more rapid than crucible oil furnaces; and that the open-flame and reverberatory furnaces far surpass the other types at all capacities.

The pit oil furnaces with several crucibles (subdivisions 21, 22, and 23 of the large table) are not represented by curves, because the figures tabulated under "time per hundredweight of metal melted" are per furnace, and not per hundredweight per crucible. In these furnaces

the length of the heat is longer per hundredweight per crucible than the average in any of the other types of furnaces; hence, unless they

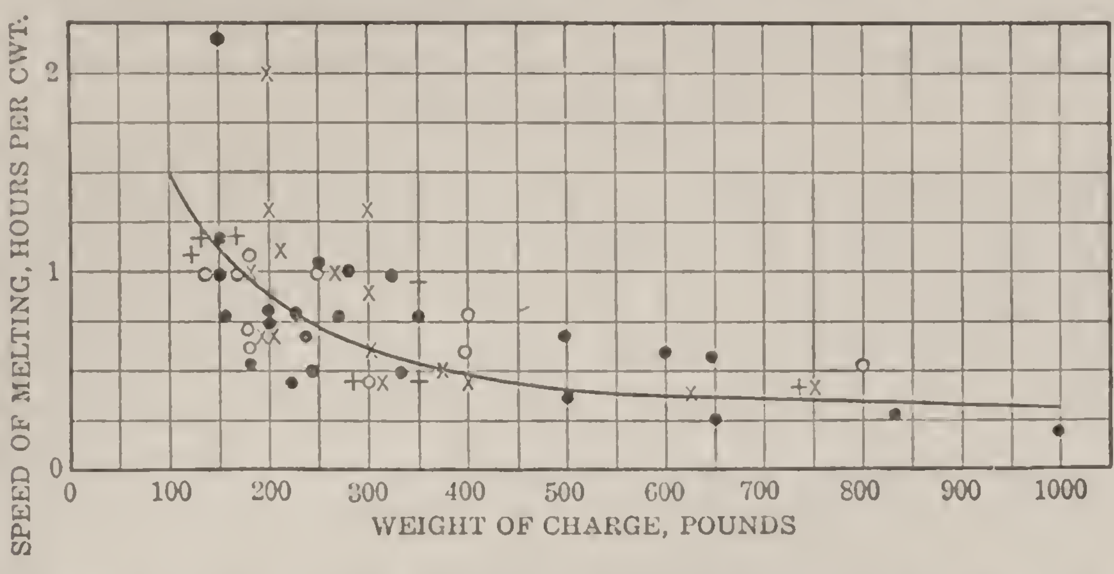


FIGURE 6.—Relation of speed of melting to weight of charge in crucible oil furnaces. ● furnace with low-pressure air burner, melting low-zinc alloys (subdivisions 16, 17, and 28 of large table); ○ furnace with low-pressure air burner, melting high-zinc alloys (subdivisions 18 and 29); × furnace with high-pressure air burner, melting low-zinc alloys (subdivisions 19 and 30); + furnace with high-pressure air burner, melting high-zinc alloys (subdivisions 20 and 31).

can be forced faster than is indicated in the replies tabulated in subdivisions 21, 22, and 23 of the table they offer no advantages on the score of low zinc loss or freedom from gas absorption.

The variation in speed of melting of the furnaces represented by the replies received was 6 to 6.3 hours per hundredweight at one extreme, on 50 to 75 pound charges in coke and coal furnaces, to 0.07 hour per hundredweight on 2,500-pound charges in an open-flame oil furnace, and 0.02 hour per hundredweight on 14,000-pound charges in a reverberatory oil furnace.

The method used by the firm making reply 163 (subdivision 1 of the table), of leaving a "heel" of molten metal in the pot from one heat to another, in order that the heat may be transmitted from the walls of the crucible to the solid metal of the next charge through metal instead of largely through gas, as is the case, until the new charge begins to melt, when no heel is left, has been

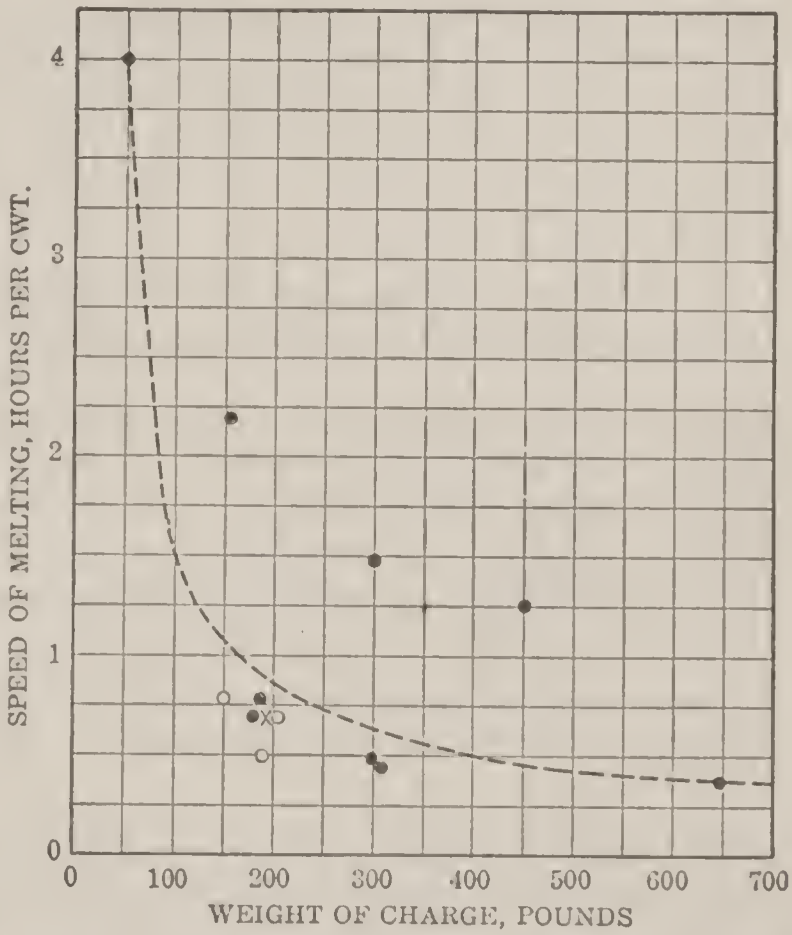


FIGURE 7.—Relation of speed of melting to weight of charge in pit, crucible, gas furnaces. ● natural-gas furnace (subdivisions 24 and 27); ○ city-gas furnace (subdivision 25); × producer-gas furnace (subdivision 26). The data on gas furnaces are too few to fix the position of the curve. The same curve used in figure 6 has been represented.

successfully used in the writer's experience in a somewhat similar case on nonferrous alloys other than brass and bronze. Leaving a heel of metal increases the speed of melting, and therefore the output and the fuel efficiency.

CRUCIBLE LIFE.

In furnaces using crucibles the item of crucible cost, that is, crucible life, is very important. The life of the crucibles has been plotted against their size in figures 11, 12, and 13.[a] A new crucible is supposed to hold about 3 pounds of molten metal per maker's number; that is, a new No. 60 crucible holds 180 pounds if filled full. The

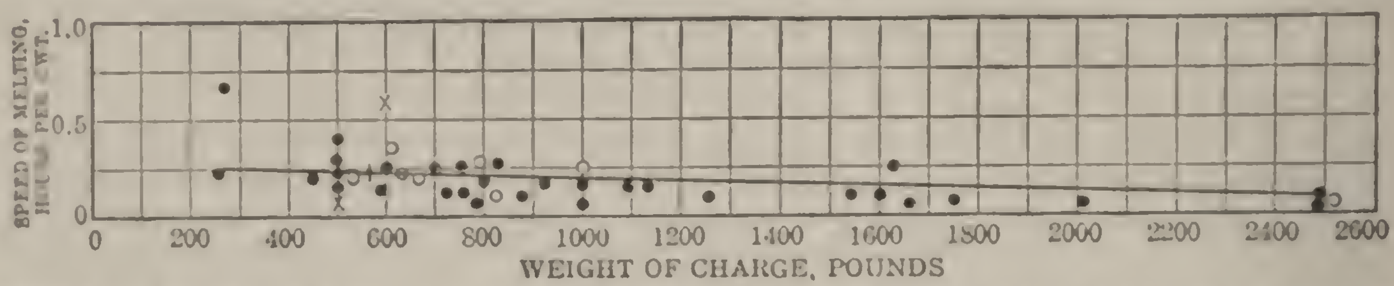


FIGURE 8.—Relation of speed of melting to weight of charge in open-flame oil or natural-gas furnaces. ● open-flame oil furnace, melting low-zinc alloy (subdivision 32 of large table); ○ open-flame oil furnace melting high-zinc alloy (subdivision 33); × open gas-flame furnace, melting low-zinc alloy (subdivision 34); + open-flame gas furnace, melting high-zinc alloy (subdivision 35).

usual charge is nearer $2\frac{1}{2}$ times the maker's number. If the crucible number is not given, the charge in pounds is divided by $2\frac{1}{2}$ to get the approximate number. This is also done with special forms of crucibles when the maker's number does not bear the above-mentioned relation to the charge.

In case an average figure is given for the life of several sizes, this has been plotted for each size, and where the limits of the life are given

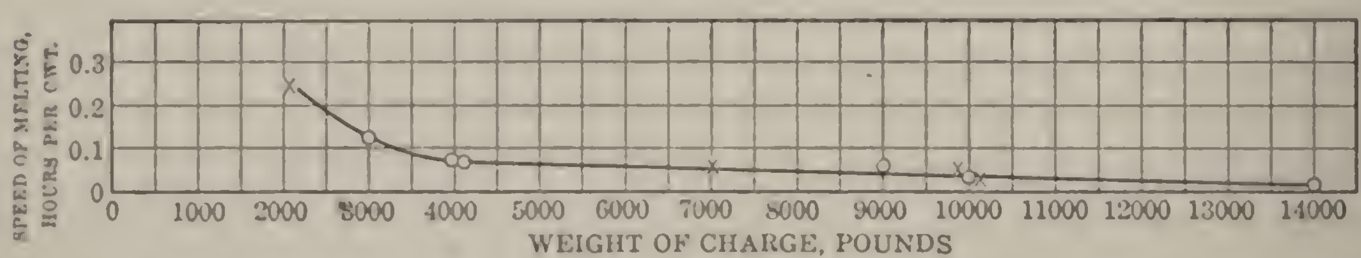


FIGURE 9.—Relation of speed of melting to weight of charge in reverberatory furnaces. ○ reverberatory oil furnace (subdivisions 36 and 37 of large table); × reverberatory soft-coal furnace (subdivisions 38 and 39).

the average is taken; that is, if a reply states that Nos. 40, 60, and 80 crucibles are used and that the life is 20 to 30 heats, 25 heats has been the figure used for each of the three sizes in plotting the curves.

Figure 11 shows the life of crucibles in pit anthracite-coal furnaces; figure 12, in pit and tilting coke furnaces; and figure 13, in pit and tilting oil furnaces. The most striking point is the amazing variation in the life of the same size of crucible under approximately the same

[a] The curves are merely tentative, to express the facts that crucible life decreases with increase in size and that the life in tilting furnaces is longer than in pit furnaces. The curves are approximations to the averages reported, but do not necessarily represent the averages for similar foundry conditions.

conditions. The variation is so great that the exact form of the curves is not certain. The curves drawn for pit coal and coke furnaces are the same. Although Replies 8, 36, and 79 state that the crucible life is less in oil than in coal or coke furnaces, Replies 3 and 188 state the

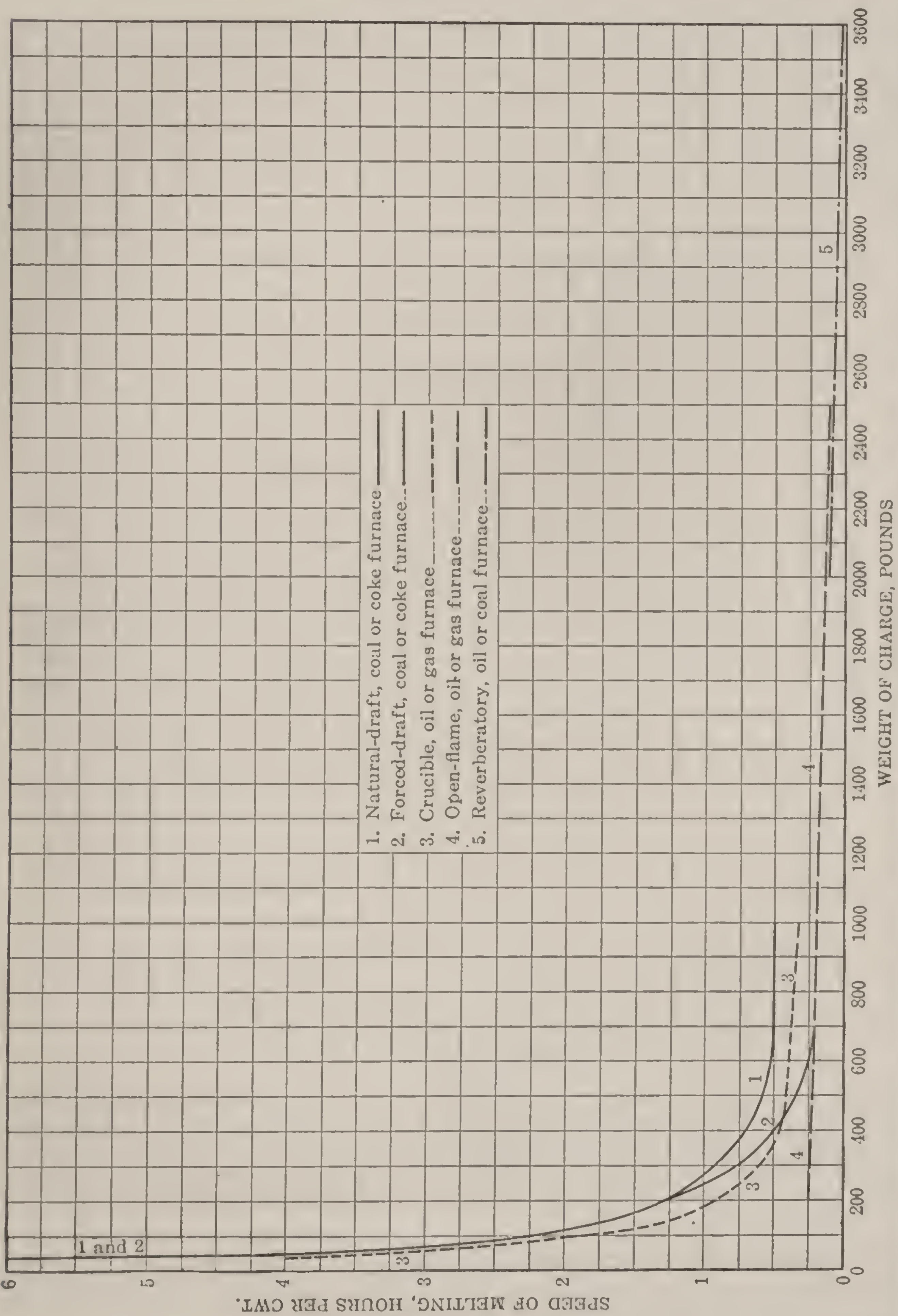


FIGURE 10.—Curves showing averages of data as to relation of speed of melting to weight of charge in five types of furnaces. The curves show the average speed at which furnaces of different types and sizes are actually run, but do not necessarily represent absolutely comparable conditions.

reverse to be true, and Replies 14, 75, and 186, covering both fuels, note no appreciable difference, and the curves indicate that the pit oil furnaces average a slightly better crucible life than do pit coal or coke furnaces, as would be expected from the fact that the ash and

clinker in the coal and coke furnaces have a tendency both to slag away the fire clay in the crucible and to adhere to it, and they have to be knocked off when the crucible is pulled.

Gas is claimed to give a longer life than coal or coke in Replies 12 and 108, but Reply 201 claims the reverse.

With increase in the size of the crucible the life decreases rather rapidly in all furnaces; hence the factor of crucible cost works directly against increase in size, which has proved to be beneficial as to speed. In pit furnaces the crucible cost, coupled with the trouble occasioned when a crucible breaks in the fire, the labor of carrying a

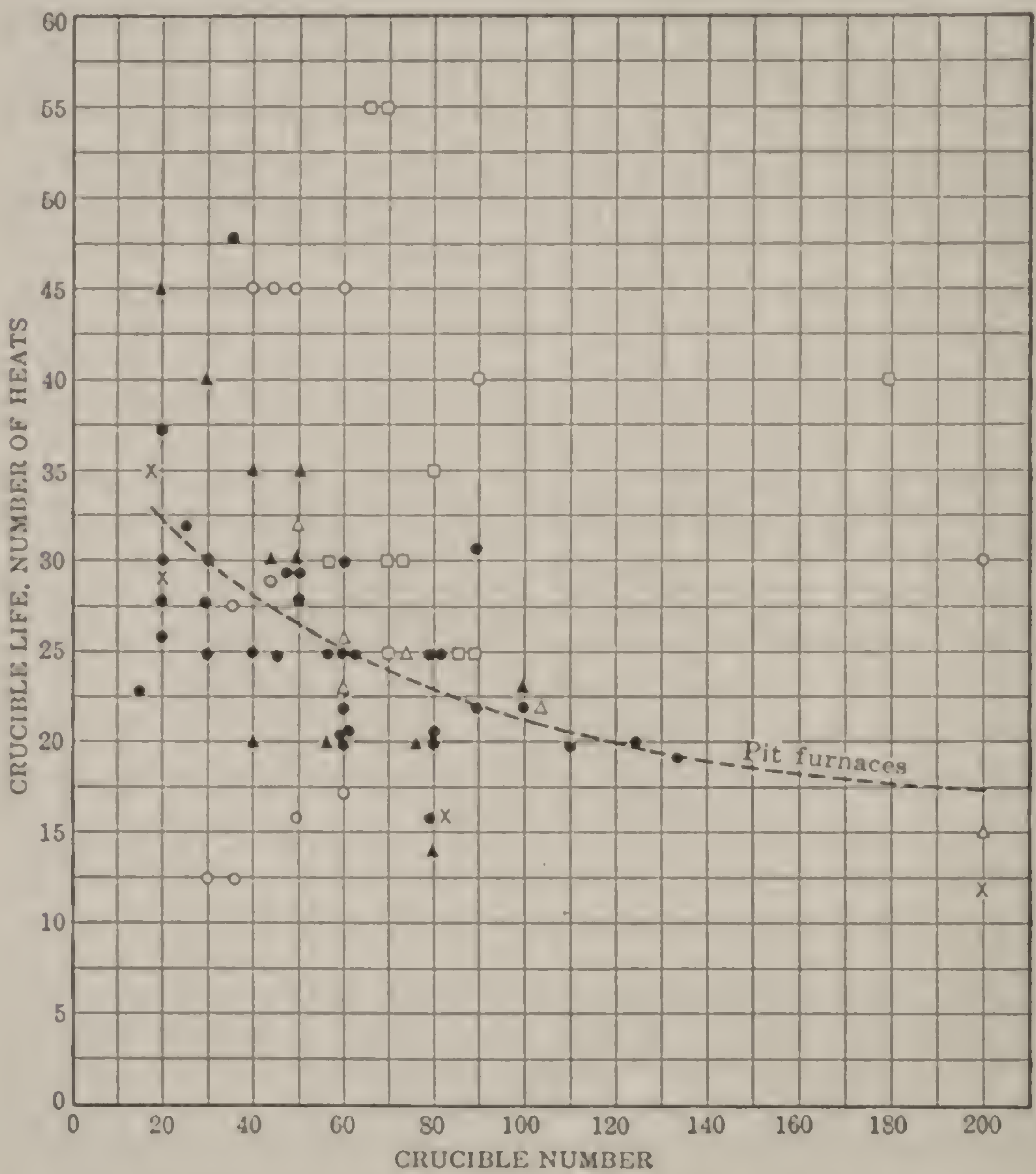


FIGURE 11.—Relation of size of crucible to its life, coal furnaces. ● round, natural-draft furnaces melting low-zinc alloys (subdivision 7 of large table); × square, natural-draft furnaces melting low-zinc alloys (subdivision 8); ○ round, natural-draft furnaces melting high-zinc alloys (subdivision 9); □ square, natural-draft furnaces melting high-zinc alloys (subdivision 10); ▲ round, forced-draft furnaces melting low-zinc alloys (subdivision 11); △ round, forced-draft furnaces melting high-zinc alloys (subdivision 12).

large crucible to the mold, and the difficulty of pouring from it, prevents increasing the furnace size beyond a capacity of about 400 pounds, except in rare cases.

Figures 12 and 13 show what a great increase in life is obtained by using a tilting instead of a pit furnace. Figure 13 also shows that

high-pressure air is rather harder on the crucible than is low-pressure air. Figures 11 and 12 indicate that it does not appear to make much difference in the life of the crucible whether natural or forced draft be used in a pit coke or coal furnace.

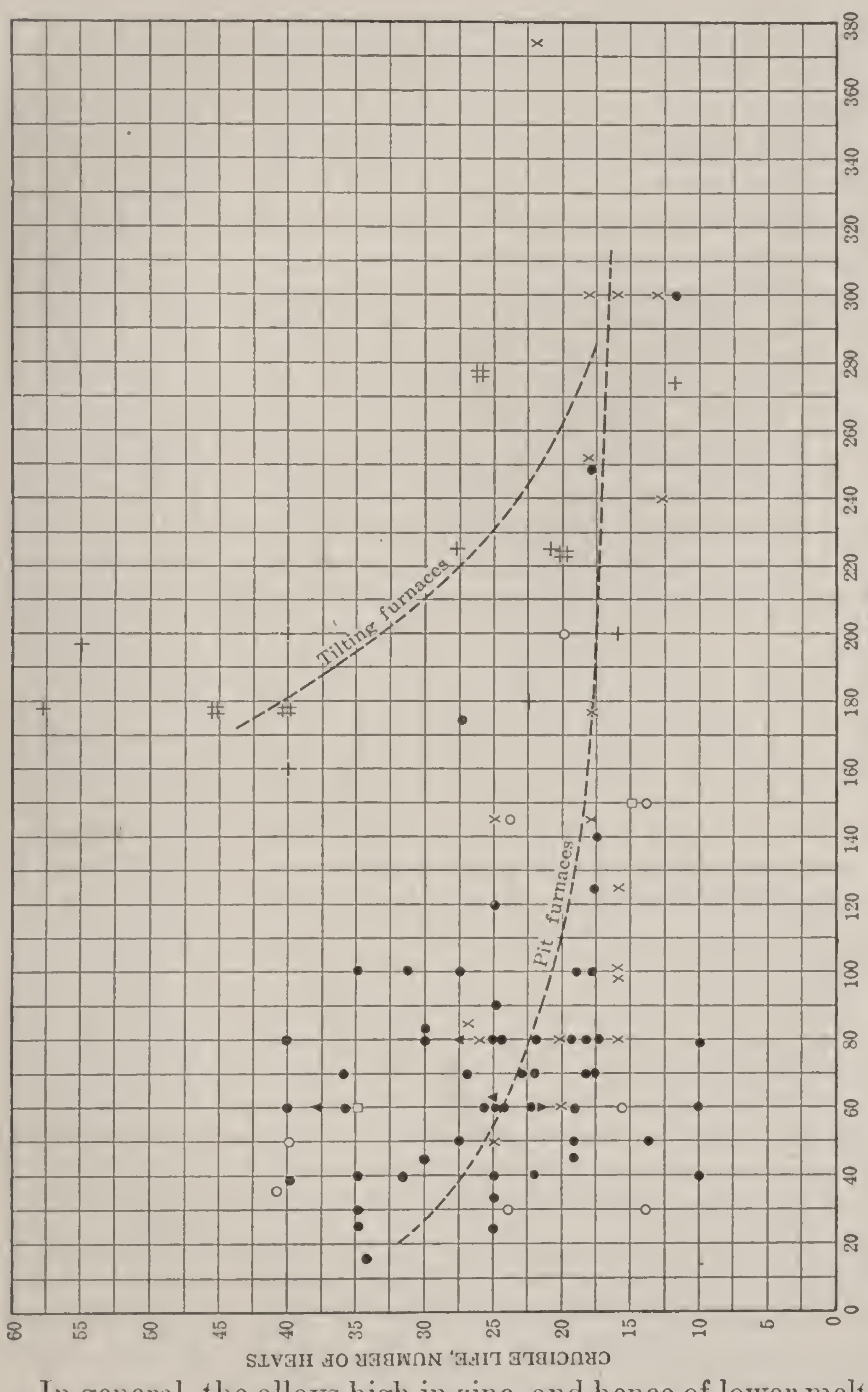


FIGURE 12.—Relation of size of crucible to its life, coke furnaces. ● round, pit, natural-draft furnaces melting low-zinc alloys (subdivision 1 of large table); × square, pit, natural-draft furnaces melting low-zinc alloys (subdivision 2); ○ round, pit, natural-draft furnaces melting high-zinc alloys (subdivision 3); □ square, pit, natural-draft furnaces melting high-zinc alloys (subdivision 4); △ round, pit, forced-draft furnaces melting low-zinc alloys (subdivision 5); ▽ square, pit, forced-draft furnaces melting high-zinc alloys (subdivision 13); × tilting, forced-draft furnaces melting high-zinc alloys (subdivision 13); # tilting, forced-draft furnaces melting high-zinc alloys (subdivisions 14 and 15). If the maker's number of the crucible is not specified in the table, the weight of the charge divided by 2½ was taken as the crucible number in plotting the curves.

In general, the alloys high in zinc, and hence of lower melting point, allow a longer crucible life than those low in zinc.

One variable in the life of the crucible is, of course, the quality of the crucible itself, its composition, its uniformity, its firing in the

kiln, and, in general, everything that happens to it before it leaves the maker's hands. There is undoubtedly a vast variation in the quality of crucibles, but it appears that, although one plant will state that the crucible made by A is the best and that that made by B is

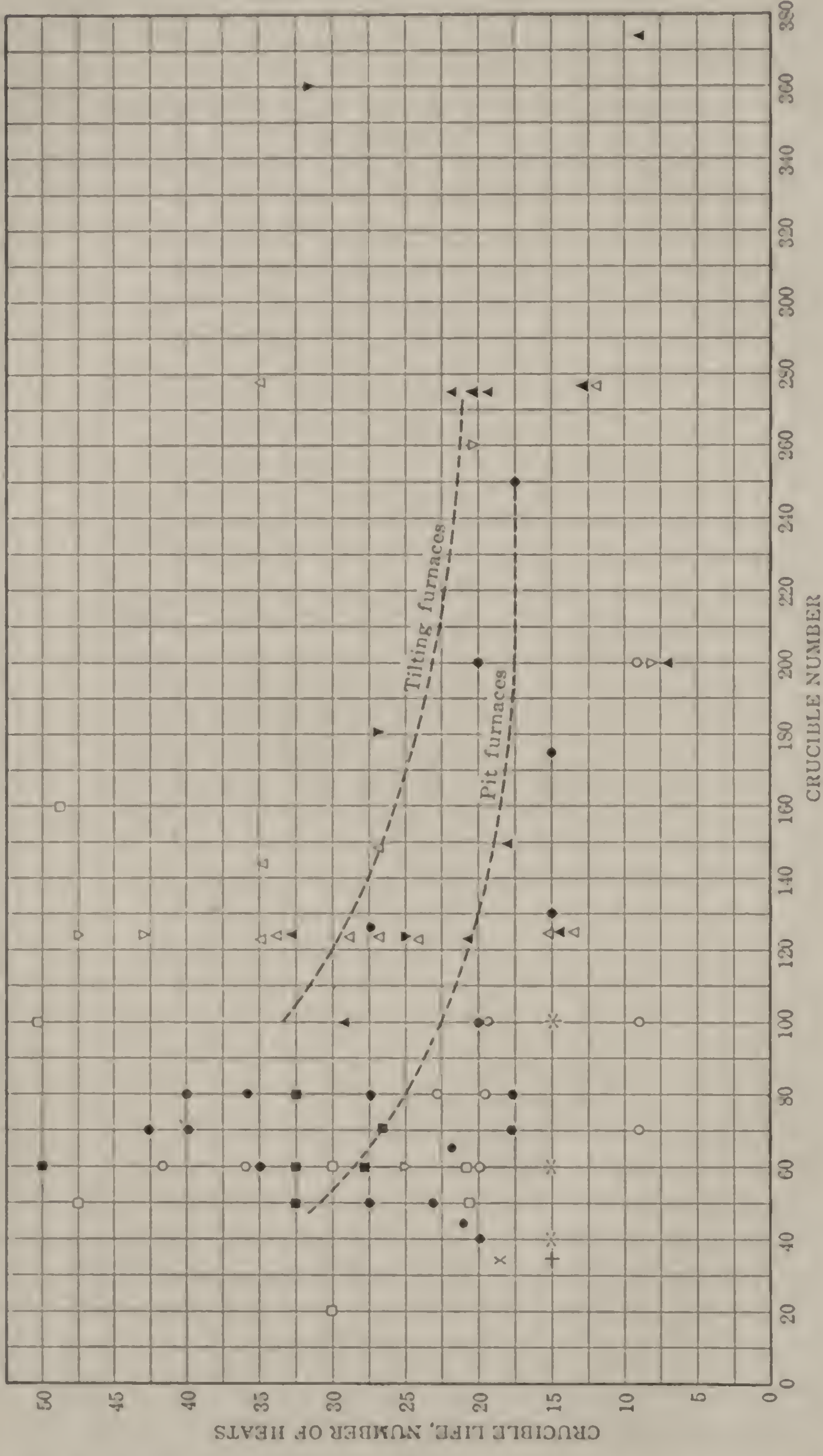


FIGURE 13.—Relation of size of crucible to its life, oil furnaces. ● pit furnaces, low-pressure air burner, low-zinc alloys (subdivisions 16 and 17); ■ pit furnaces, low-pressure air burner, high-zinc alloys (subdivision 18); ○ pit furnaces, high-pressure air burner, low-zinc alloys (subdivision 19); □ pit furnaces, high-pressure air burner, high-zinc alloys (subdivision 20); + pit furnaces taking several crucibles, high-pressure air burner, low-zinc alloys (subdivision 21); × pit furnaces taking several crucibles, high-pressure air burner, high-zinc alloys (subdivision 22); * pit furnaces taking several crucibles, natural-draft pan burner, low-zinc alloys (subdivision 23); ▲ tilting furnaces, low-pressure air burner, low-zinc alloys (subdivision 28); ▼ tilting furnaces, low-pressure air burner, high-zinc alloys (subdivision 29); △ tilting furnaces, high-pressure air burner, low-zinc alloys (subdivision 30); ▽ tilting high-pressure air burner, high-zinc alloys (subdivision 31). If the maker's number of the crucible is not specified in the table, in plotting the curves the crucible number was taken as the weight of the charge in pounds divided by 2½.

the worst, another plant, working under as nearly the same conditions as are ever found in two different foundries, will call A's the worst and B's the best. In other words, there seems to be as much variation between different lots of crucibles from the same maker

as there is between those from different makers. One exception only need be noted—in forced-draft, tilting, coke furnaces a number of users report consistently better results from an imported crucible than they have been able to get from any make manufactured in this country.

The great variation in life in the same type of furnace and on the same alloy shows that, aside from the effect of the melting point of the alloy, the chief factor in the life of a crucible is not the type of furnace so much as it is the treatment it receives by maker and user, and the variations in treatment by the user seem to be far greater than the difference in quality of the crucibles when they leave the maker.

PROPER TREATMENT OF CRUCIBLES IN THE FOUNDRY.

Although crucibles are free from moisture when removed from the kiln, they rapidly absorb it, and many take up 5 per cent of moisture during shipment from maker to user. If, instead of eliminating the moisture by a gradual annealing, the damp crucible is put directly into a hot furnace, or into a cold one and heated too rapidly, the moisture will be changed into steam so rapidly that the steam evolved will blow pieces of the crucible off bodily; that is, the crucible will "scalp."

To prevent this the crucible must be raised from room temperature to a temperature somewhat above the boiling point of water very gradually, so that the moisture may be driven off gradually without "scalping" of the crucible.

There is always an abundance of waste heat that can be utilized for warming the place where the crucibles are stored. A common place for crucible storage in foundries using pit furnaces is just back of the battery of furnaces. The waste heat may also be led through a special oven, so provided with dampers that the heat may be gradually admitted for annealing a fresh batch of crucibles. After annealing has been finished the oven may be utilized as a warm storeroom. Crucibles are sometimes stored above a core oven, or, in a rolling mill, above an annealing furnace, a good practice if the oven or furnace is run constantly enough to keep the crucibles dry.

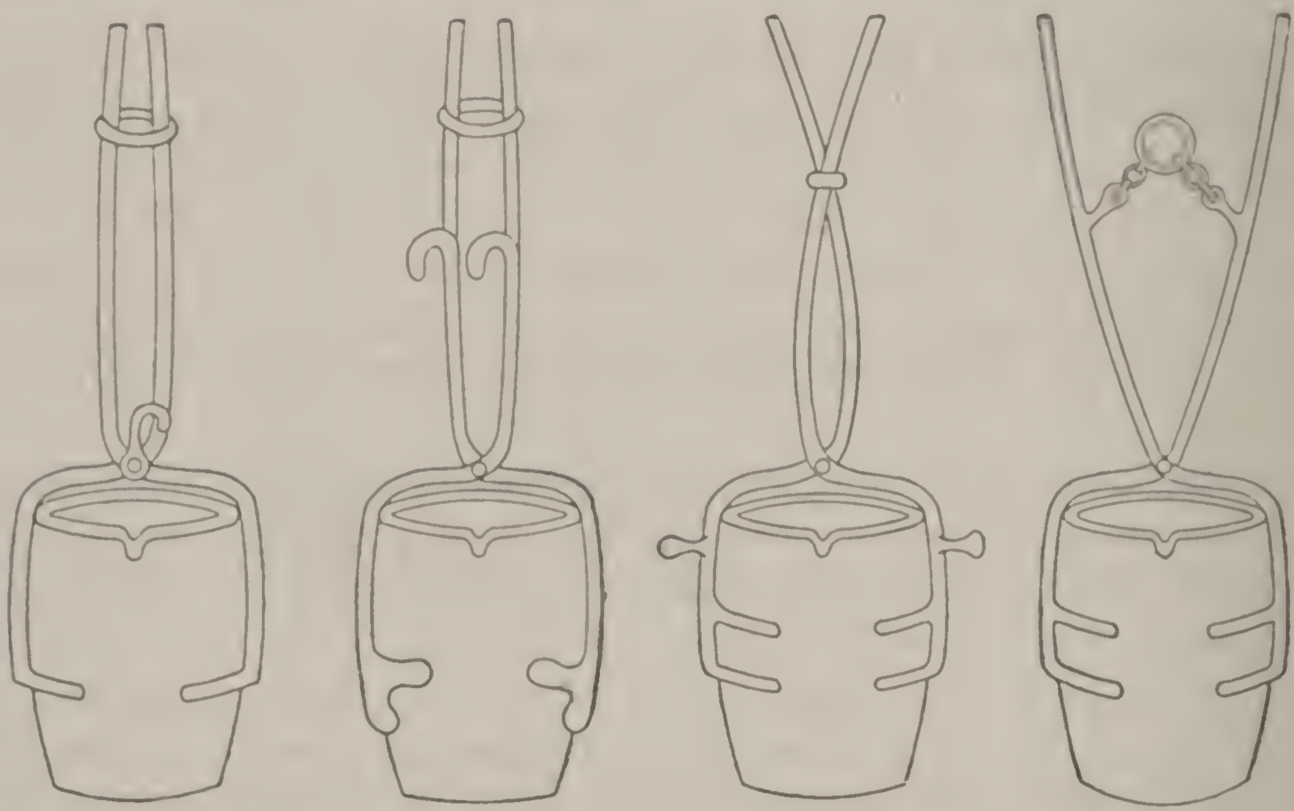
Most foundrymen are fairly careful about annealing their crucibles, but many do not pay enough attention to the tongs used and the way the crucibles are handled with them. The greatest damage to crucibles is done with improper tongs or with tongs improperly handled.

There are several different types of crucible tongs for pit furnaces, some of which are illustrated in fig. 14. No. 1 is a one-prong type, mainly used in pit furnaces burning anthracite coal, as in rolling mills. The prong comes just below the bilge, because the diffi-

culty of poking tongs down through the anthracite and its ash is greater than through coke and its ash, so that tongs that come farther down the crucible are a little harder to use in coal furnaces. The handles are spread, the tongs squeezed into place, and a link slipped over them to seat them tightly. A mechanical hoist, operated by hand, air, or electricity, is fastened into the hook at the pivot.

No. 2 is the spade type. In the figure this type is shown with hooks on the handles for lifting the pot by hand without mechanical hoist. An iron bar is passed through the hooks and the pot lifted by two men, one on each side of the furnace.

No. 3 represents a two-prong tong, one prong being above and one below the bilge, with trunnions for pouring. On Nos. 1 and 2 the tongs are used merely for lifting the crucible from the fire and setting



1 2 3 4

FIGURE 14.—Four types of crucible tongs: *1*, single-prong type; *2*, spade tong; *3* and *4*, double-prong tongs. *1*, *2*, and *3* are of the "pinch" type; *4* is of the "grab" type.

it into the pouring shank. With No. 3, the crucible is held by the tongs during pouring, being carried on a shank of such form that the shank may be held horizontal while the tongs are tilted on the trunnions; or, a bail may be attached to the trunnions and the tongs and crucibles held by a traveling crane.

In the first three forms the crucible is pinched tightly in the tongs and the tongs are held in place by a link slipped over the handles. To put on the link and get it tight is hot work, as it must be done directly over the open fire. Hence the furnace tender, instead of slipping the link down just tight enough to hold securely, is prone to jam it down, even driving it down with a poker or a skimmer.

The pinching of the crucible may in this way be very severe, as the hot crucible is soft and leathery and gives somewhat readily.

It is common to see crucibles, the mouths of which have been pinched into a distinctly oval shape. Every time the crucible is thus strained it is weakened and its life greatly shortened. To prevent this excessive pinching of types designated 1, 2, and 3, each of which may be termed the "pinch" type, the type designated 4 in the figure, or the "grab" type, has been devised. This is intended for use with a mechanical hoist and may be made with one prong or with a spade prong if desired. In using the grab type the tongs are hooked into the hoist and lowered into place, the tongs being spread, and gently seated in place; the hoist is then slowly started upward, when the tongs take hold and the crucible is held by its own weight.

A toggle joint may be used instead of the chain illustrated, and in some cases hooks like those on No. 2 are put on, and the hoist carries an equilateral triangle, vertex down, which is hooked into both hooks and draws them down by the weight of the crucible.

For use in oil or gas furnaces the grab type with a toggle joint may be further improved by making the joint with a pair of stop lugs so that the tongs can open only far enough to clear easily the bilge of the crucible.

The handles of the grab type are often bent down at right angles just above the chain, hooks, or toggle joint, so that the tongs may be guided into place without getting the hands directly over the open furnace.

Several foundries that use the grab type of tongs testified that with that type they could without question handle crucibles up to No. 250, holding about 650 pounds of metal. No instance of a crucible having been dropped by such tongs has been reported. Every firm using this type was enthusiastic in its favor, and said that no other form would be used, as the grab type greatly increased the crucible life. The long life in the natural-gas pit furnaces of the crucibles of the firm supplying Reply 15 is ascribed largely to the use of the grab tongs. This type seems to deserve a much wider use than it now has.

No matter what type of tongs be used, if they get out of shape and do not fit the crucible at all points, excessive strain is put on the crucible at the points where they do touch. In the same way, the spade and two-prong tongs, having more bearing surface than the one-prong, divide the strain more evenly.

Some foundries have only one size of tongs, and if now and then they have to use a larger or smaller crucible than the size ordinarily used, they will use tongs that do not fit it at all. This practice is fatal to the life of the crucible.

A crucible grows slightly smaller with use, owing to oxidation and wearing away of the surface. One foundry that reports an ex-

ceptional crucible life has three sets of tongs, differing slightly in size, which are selected according to the age of the pot.

An easy way to keep tongs in proper shape is to have a cast-iron form just the size of the crucible used. As soon as it is seen that the tongs are slightly out of shape, they can be heated and pounded back into shape over the iron form.

Crucible hoists have been patented with which the crucible is raised on the block on which it sets, the block being in turn on a pillar which is raised up through the bottom of the furnace by air or hydraulic pressure, thus doing away with the lifting tongs entirely. There would be considerable difficulty in adapting this device to a coke or coal furnace, but it should be practical as applied to oil or gas pit furnaces. A shank can be designed that will take the crucible from the block without the use of tongs, one that would need little modification being described by Marteil.[a] Such a scheme, aside from putting the crucible to less severe usage, would allow the use of approximately cylindrical crucibles, such as are often used in tilting furnaces, a practice that would give more heating surface per unit volume of metal, and hence a faster melting speed and higher fuel efficiency.

A type of oil or gas furnace recently patented is made with the furnace shell hinged so that it can be opened and the crucible taken out by the use of a hinged or "scissor" pouring shank. However, the drawbacks to such a plan are many.

In rolling mills, the crucibles are usually lifted from the furnaces by a rope hoist operated by hand. The metal is poured while the crucible is still suspended by the hoist, without putting it in a pouring shank. The hand-operated rope hoist has been supplanted by electric hoists in a few mills, and controversy rages among mill men as to which is better, the hand or the electric hoist. The hand hoist requires hard muscular exertion on the part of the workmen, but can be operated more smoothly than the electric hoist, thus insuring steadier pouring and causing less spilling of metal. One progressive mill states, however, that it prefers the spilling of a little metal to the strenuous objection of the workmen to the hand hoist after once having used the electric hoist.

An oxidizing atmosphere will burn the graphite from the outside of the pot and weaken it; hence for long crucible life in any furnace, especially in oil or gas furnaces, a reducing flame should be maintained. If an oxidizing flame is trained directly on the crucible the crucible becomes badly scored at that point. As the burners requiring low-pressure air and high-pressure oil are more easily controlled so as to give a reducing flame, and as they usually give a

[a] Marteil, V., Alliages et fonderie de bronze, 1910, p. 61.

wider cone of flame, as ordinarily operated, they are easier on crucibles than the burners using high-pressure air.

If oil be allowed to spray strongly on a cold crucible before the burner is lighted, the oil will soak in, and "scalping" may result when the furnace becomes hot.

Sulphur dioxide from fuels high in sulphur is said to be highly deleterious to the crucible.

Allowing the crucible to remain in the fire longer than is necessary; that is, not taking the pot out when the metal is ready, or allowing the metal to "soak," increases the wear on the crucible; hence promptness in taking out the metal lengthens the life of the crucible and also prevents gas absorption and loss of zinc. The higher the temperature to which the metal is raised, the harder the wear on the crucible. In foundries in which alloys of several melting points are used, crucibles are usually used for part of their full life in melting an alloy with the highest melting point, and are then used for alloys with lower melting points. Thus a crucible might be used for a couple of heats of pure copper, then for phosphor bronze, then for red brass, next for yellow brass, and finally, for aluminum. Used in this way, the total tonnage melted per crucible would probably be larger than if each crucible should be used for its full life on one alloy. Between changes in the alloy melted, it is necessary to clean the crucibles well from any adhering metal to avoid contamination from the previous charge.

Another way in which crucibles are injured is by wedging them full of cold ingots or scrap, which expand as they are heated to the melting point; the crucible does not expand so much, so that a great strain may be set up and the crucible be cracked, or at least, weakened.

Crucibles may also be badly injured mechanically by carelessness in poking the fire or in knocking off slag and clinkers.[a]

Protective coatings are sometimes used in an attempt to prolong the life of the crucible. Havard[b] mentions a paint of finely pulverized carborundum fire sand mixed with water glass or boric acid, and states that there is no doubt but that for certain purposes such coatings increase the crucible life. A protective coating of a nature somewhat similar to the above is said to be largely used abroad and has recently been put on sale in this country. Reports from firms that are trying this are not based on long enough experience to be conclusive, but indicate that a saving may be effected in this way.

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[a] For articles on prolonging the life of crucibles, see Anon., Use and care of crucibles in foundry practice: Met. Chem. Eng., vol. 10, 1912, p. 182; Jour. Inst. Metals, vol. 7, 1912, p. 309; Sperry, E. S., Graphite crucibles, their use and abuse: Brass World, vol. 2, 1906, p. 1; Johnson, D., Crucible tongs: Metal Ind., vol. 5, 1907, p. 362; Keeping the tongs in shape: Metal Ind., vol. 6, 1908, p. 93; Bartley, J., Effect of crucible soaking: Metal Ind., vol. 12, 1914, p. 12.

[b] Havard, F. T., Refractories and furnaces, 1912, p. 236.

Bartley [a] states that in a coal or coke furnace with proper fuel space for a given sized crucible the use of either a larger or a smaller crucible decreases the crucible life; Bartley also brings out the important point that crucible life is shorter in square furnaces than in round ones, owing, no doubt, to the less even heating.

Wood [b] cites three rolling mills, one of which used 67 pounds of coal per hundredweight and got 25 heats for the life of a crucible, another 50 pounds of coal per hundredweight and got 33 heats, and a third 33 pounds of coal per hundredweight and got 48 heats, all with the same make of crucible.

If a crucible is not allowed to cool down very far, but is kept hot continuously, so that there is less expansion and contraction, its life is lengthened. This is one reason for the longer life of crucibles in tilting than in pit furnaces. Replies 6 and 170 show the benefits of running a crucible continuously without allowing it to cool. Continuous operation of brass furnaces for 24 hours a day is of course very rare. However, if the crucibles from a pit furnace, before they become cool, are promptly put back into the furnace after pouring, and if at night, after the last heat has been poured, the empty crucible is put back in the furnace and allowed to cool gradually with the furnace, the deterioration due to excessive expansion and contraction may be minimized.

FURNACE LININGS AND THEIR LIFE.

Questions on the material and thickness of furnace linings and on the material and shape of the furnace cover were included in the list sent out, but the replies have not been included in the tabulation. Most of the replies concerning covers for pit coal or coke furnaces stated that either flat, fire-brick covers (the rolling mills using this form almost entirely) or dome-shaped, cast-iron covers were used. Flat covers of cast steel or manganese steel were, however, highly recommended by a few users, and one firm uses a dome-shaped cover of malleable iron.

On most pit oil furnaces the covers are flat and of solid fire brick. On tilting-crucible oil furnaces they are similar, but for charging have a hole in the center, which may or may not be covered by a second smaller cover.

If a "feeder" or preheater is used, as on some pit furnaces of all types and on tilting oil and coke furnaces, it is usually fitted into a fire-brick ring, which serves as a cover to the furnace, the feeder itself not being covered.

No clear relation was found between the thickness of the lining and its life or the fuel consumption. On pit, coal, or coke furnaces

[a] Bartley, J., Crucible and furnace relationship: Metal Ind., vol. 11, 1913, p. 166.

[b] Wood, R. A., How much coal does it take to melt a pound of metal: Metal Ind., vol. 11, 1913, p. 88.

the thickness of the lining varies from 3 inches, in rare cases, up to 9 inches, also in rare cases, the great majority being about 4½ inches thick. One user of this type uses a 15-inch wall between adjacent furnaces of a battery, so that a furnace may be cool enough to allow relining even when those on each side are running.

Pit oil furnaces and forced-draft tilting coke furnaces have, on the average, a 5-inch lining. The average thickness of the lining of tilting-crucible oil furnaces is about 6 inches, varying from 4 to 10. The linings of open-flame oil furnaces of the 500 to 1,500 pounds sizes are mainly 5 to 8 inches thick, with an average of 7 inches. The very large furnaces of this type have a 12-inch lining.

Most of the egg-shaped open-flame furnaces are lined with carborundum fire sand. This is also used in pit anthracite-coal furnaces (Reply 71, subdivision 7 of the table, and Reply N, p. 118) and is used with kaolin and broken glass in one pit oil furnace (Reply 3, subdivision 16).

A somewhat similar composition which has been recommended[a] is 70 parts carborundum fire sand, 15 parts ground fire clay, 8 parts water glass, and 7 parts water. Ground magnesite brick, or high-grade fire brick bonded by tar is also recommended, and for patching furnace linings the use of such a mixture of graphite and fire clay as is used in the manufacture of crucibles and is obtainable from crucible makers is suggested.

It is stated [b] that the best fire brick for furnace linings is one high in alumina; that it should be of a basic character, so that slag will not be formed by the ash in contact with it; that it should have a smooth surface, so that clinkers will not adhere, and that it should have a high melting point.

High-temperature asbestos cement is used in one open-flame oil furnace (Reply 96, subdivision 32), and in one pit gas furnace (Reply 108, subdivision 25).

A few replies state that there is an increase in the life of the lining if special brick of the kind much used for blast-furnace linings be used instead of ordinary brick. At various plants tests of linings for pit furnaces, both of special clay and of corundite brick are now in progress and the results are reported as very promising.

Reply 152 states that the life of the lining of a tilting-crucible oil furnace has been greatly increased by the use of a plastic fire-brick composition which is tamped into place, but that this is not suitable for coke or coal furnaces.

The great majority of all furnaces, however, are lined with ordinary fire brick; if square, ordinary shapes are used; round, circle brick,

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[a] Anon., Furnace-cover linings: Foundry, vol. 41, 1913, p. 386.

[b] Editorial answer to question on fire brick: Brass World, vol. 9, 1913, p. 373.

large circular sections, or complete circles are used; other shapes are lined with special brick.

The life reported varies greatly, and is largely increased by frequent patching of worn places. The variation is extremely notable in open-flame oil furnaces, in which a lining may last from 250 heats to over 24,000, continuous operation (that is, fewer periods of expansion and contraction) and very frequent patching being conducive to long life. In general, in the same plant and under approximately equivalent conditions, for each of a given type of furnace the number of heats does not vary greatly with the size; hence the larger the furnace the less the repair cost per hundredweight of metal melted.

VARIATION IN FUEL CONSUMPTION WITH SIZE OF FURNACE.

The improvement in fuel efficiency with increase in the size of the furnace, other conditions being the same, is strikingly shown by the following tabulation compiled from replies each covering several sizes of the same type of furnace.

Relation of fuel consumption to size of furnace.

Subdivision reference to large table.	Reply No.	Fuel.	Weight of charge.	Fuel per cwt.
			Pounds.	*Pounds.*
1	82	Coke	200	60
			310	45
			675	33
1	188	.....do	120	85
			180	57
			140	43
2	74	.....do	400	33
			650	30
			1,000	25
7	61	Coal	75	63
			150	38
4	11	Coal (forced draft)	100	29
			150	26
			[a] 300	27.5
				Gallons.
32	67	Oil (open flame)	600	2.3
			1,540	2.0

[a] Reply 11 states that too wide a fuel space was allowed in the 300-pound furnace.

Reply 79, subdivision 8, of the large table, shows a decrease in efficiency with increase in size of charge but does not consider this result normal.

Reply 63, subdivision 32, also shows a decrease, but ascribes it to the fact that the larger furnace was not charged to as near its capacity as the smaller. Claims of furnace makers for all types of furnaces show that a distinct increase in fuel efficiency is to be expected with increase in size, and this rule holds in general.

In order to show the general trend of the improvement in fuel efficiency with increase in furnace capacity, as well as the wide variation in fuel consumption, on the same type and size of furnace and same

class of alloy, the curves in figures 15 to 19 have been plotted to show the relation of weight of charge to fuel consumption. In all, there is indicated a distinct tendency for the efficiency to improve as the size increases, but the wide deviations from the curves, which are drawn in merely as an attempt to indicate an average, shows the vast effect of the variations in foundry conditions and in the operation of the furnaces. Figures 18 and 19 have been drawn to a scale different from that used in figures 15 to 17.

A few general conclusions, but merely qualitative ones and already generally accepted, might be drawn from the curves, such as that fuel

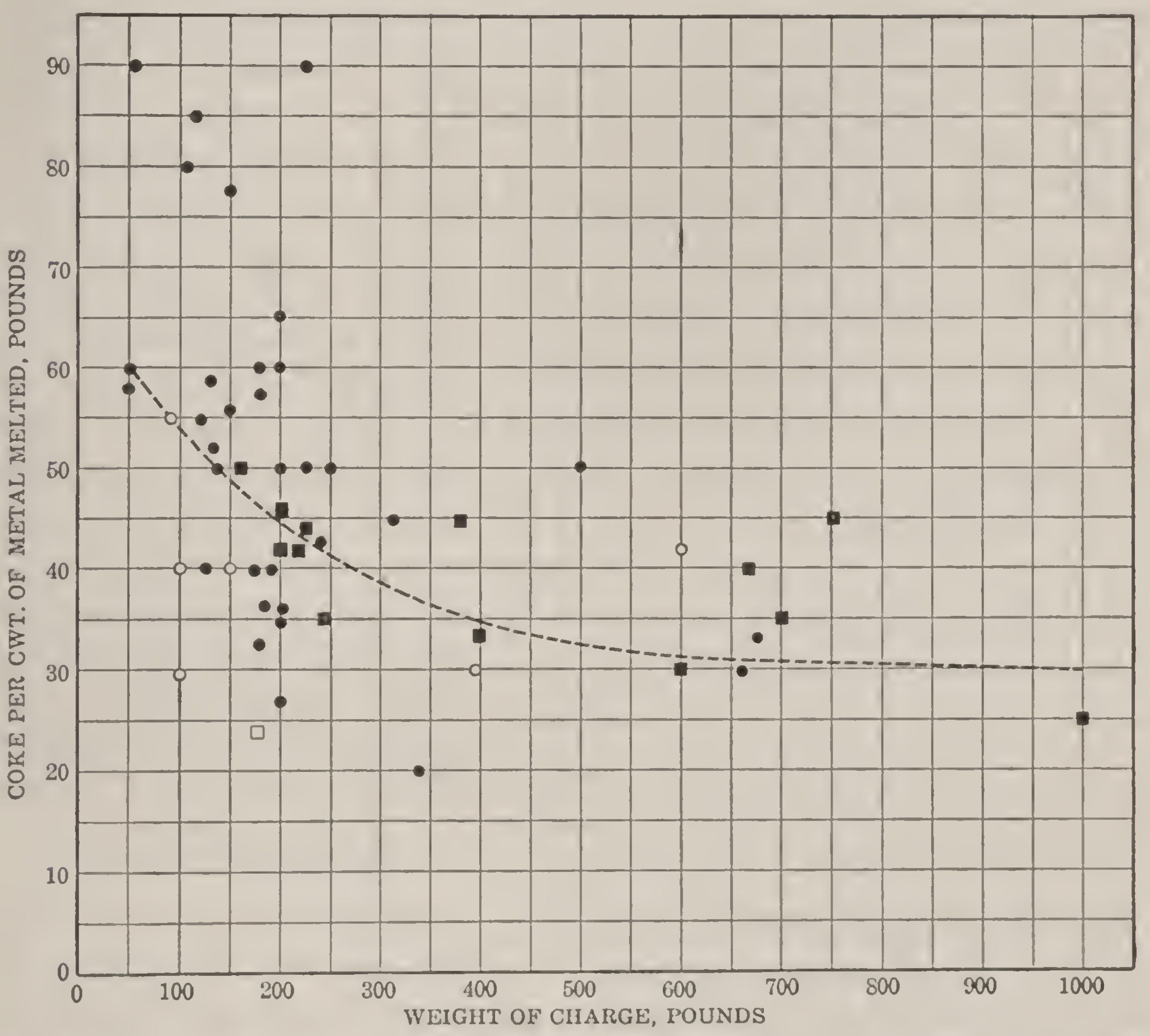

FIGURE 15.—Relation between weight of charge and fuel consumption in natural-draft coke furnaces. ● round, pit furnace, low-zinc alloys (subdivision 1 of large table); ■ square, pit furnace, low-zinc alloys (subdivision 2); ○ round, pit furnace, high-zinc alloys (subdivision 3); □ square, pit furnace, high-zinc alloys (subdivision 4).

efficiency improves with increase in furnace size, and that alloys high in zinc take a little less fuel than those low in zinc.

Figures 15 and 16 show nothing conclusive to prove whether round or square coal or coke furnaces are more efficient, and figure 18 shows no appreciable difference in the oil consumption with high-pressure and with low-pressure air on the burners. The tentative curves have been plotted together in figure 20, and if the average curves from the

data reported be taken, it would appear that a given weight of anthracite coal would melt more metal than the same weight of coke, but this conclusion is by no means definitely settled.

If the trend of the tentative average curves be accepted, it would seem also that no appreciable difference in fuel consumption was obtained in small pit furnaces between using natural and forced draft. There is, however, no question but that the larger sizes of tilting, forced-draft coke furnaces are far more efficient in fuel consumption than pit furnaces using natural draft.

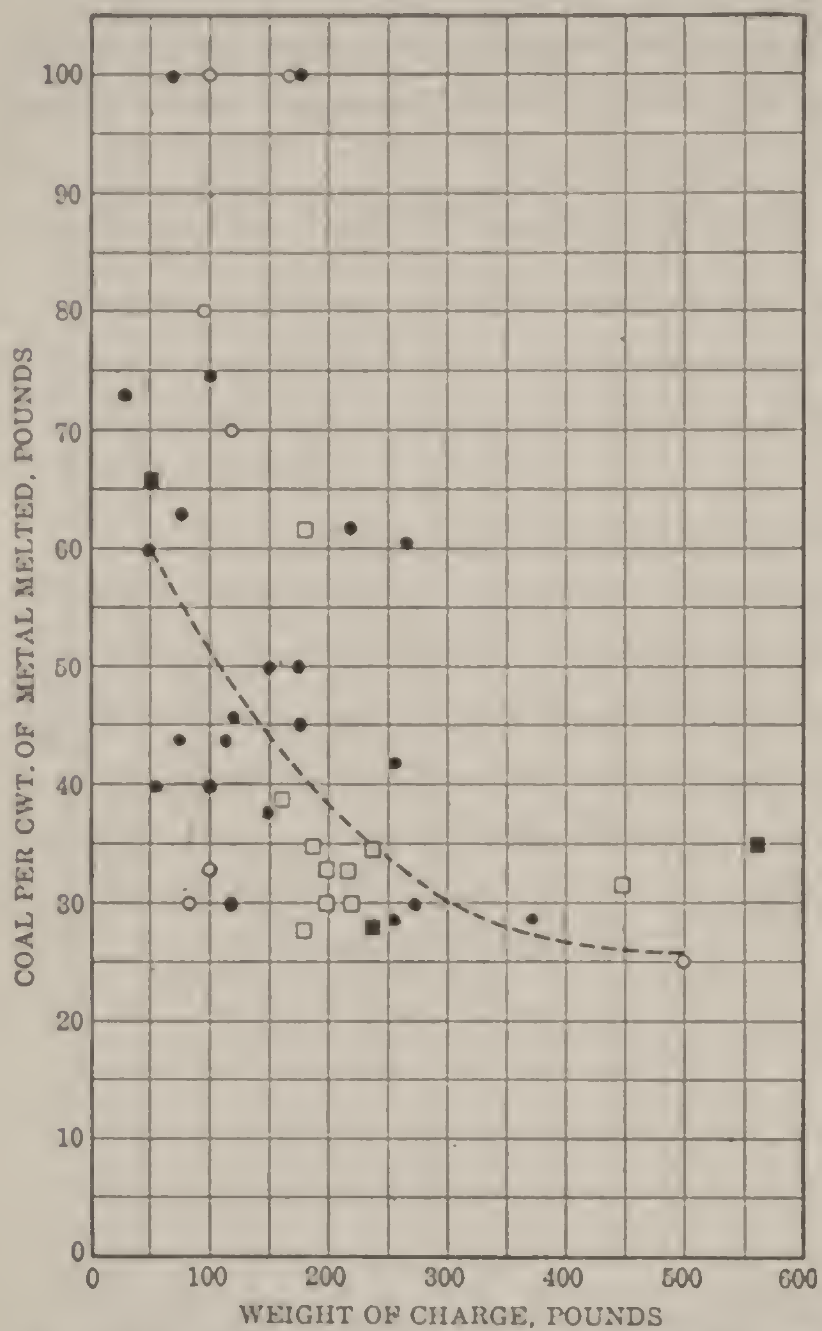

FIGURE 16.—Relation between weight of charge and fuel consumption in natural-draft coal furnaces. ● round, pit furnace, low-zinc alloys (subdivision 7 of large table); ■ square, pit furnace, low-zinc alloys (subdivision 8); ○ round, pit furnace, high-zinc alloys (subdivision 9); □ square, pit furnace, high-zinc alloys (subdivision 10).

There is not much difference between the average fuel consumption of crucible oil or gas furnaces and that of the open-flame or reverberatory type in the sizes common to both types. What advantage there is is naturally on the side of the open-flame furnace. The improvement in fuel efficiency in the oil furnaces with increase in size is not so marked as in coal or coke furnaces, although when the huge reverberatories are reached the oil consumption is very materially lowered.

MELTING LOSSES.

In figure 21 the net melting loss, or "shrinkage," as it is commonly termed in the foundry, has been plotted against the zinc content of the alloy melted by various furnaces. If the net loss was not given in the replies, but the gross loss was, the net loss has been assumed as two-thirds of the gross. The bunching of points indicating zinc contents of 5 and 35 per cent is because the bulk of the replies were for either red or yellow brass.

Under strictly comparable conditions the loss would increase with the zinc content. That the figure does not show this relation and does not show any one type of furnace to give notably higher or lower

loss than any other, indicates that more depends on the operation of any furnace than on the furnace itself.

It would be a hopeless task to determine from figure 21 which type of furnace gives the lowest loss for any given alloy, particularly when it is remembered that some of the high losses plotted on high-zinc alloys for the open-flame furnaces are from figures supplied by firms

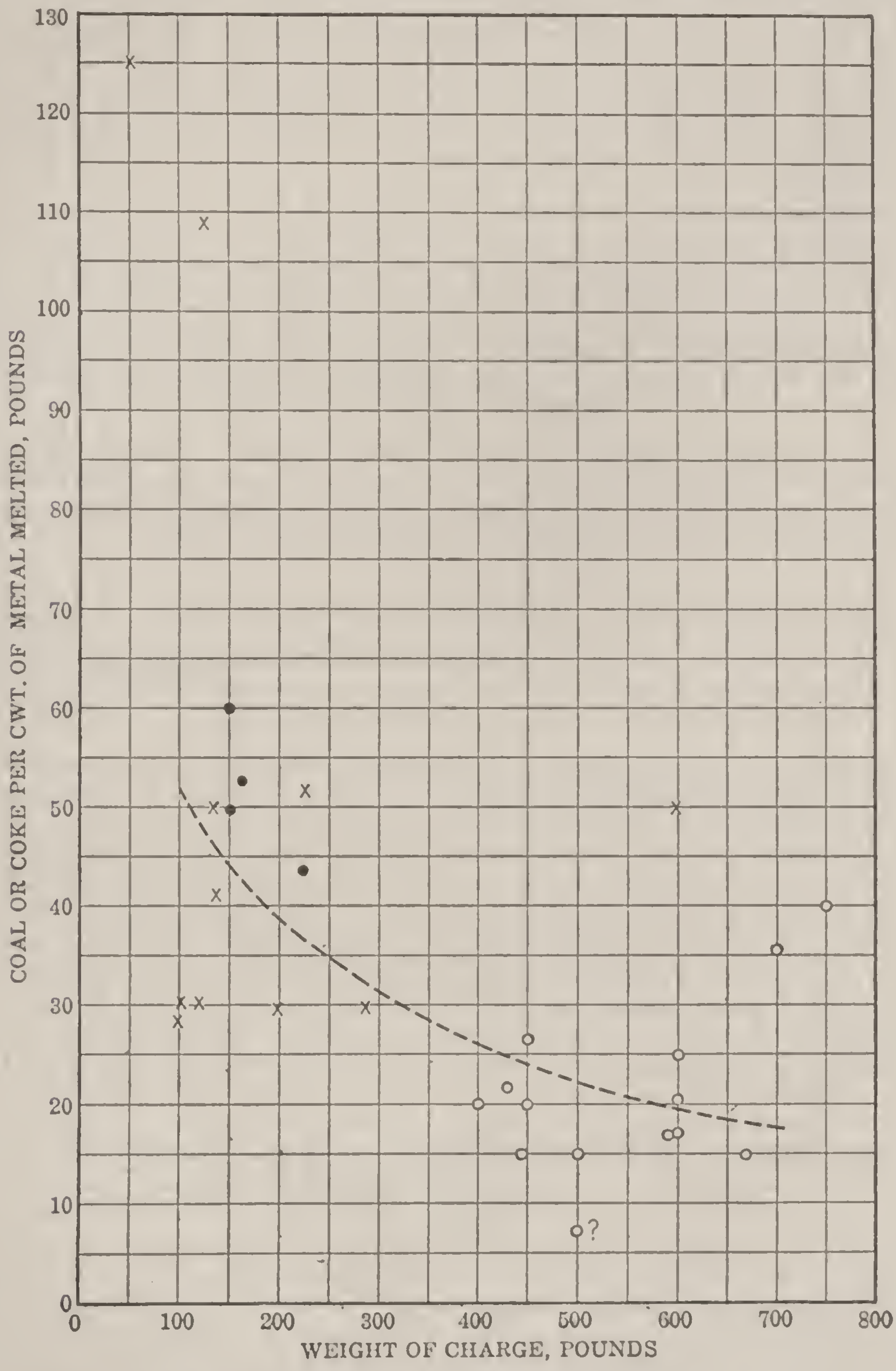

FIGURE 17.—Relation between weight of charge and fuel consumption in forced-draft coke or coal furnaces. ● pit coke furnace (subdivisions 5 and 6 of large table); × pit coal furnace (subdivisions 11 and 12); ○ tilting coke furnace (subdivisions 13, 14, and 15).

that have given such furnaces only a short trial and then discarded them, whereas some of the lowest points for high-zinc alloys in these furnaces are from data supplied by firms melting a hugh tonnage of these alloys yearly. The figure shows some slight increase in melting

loss with increase in the zinc content of the alloy, but when it is recalled that the actual tendency toward loss in melting increases in

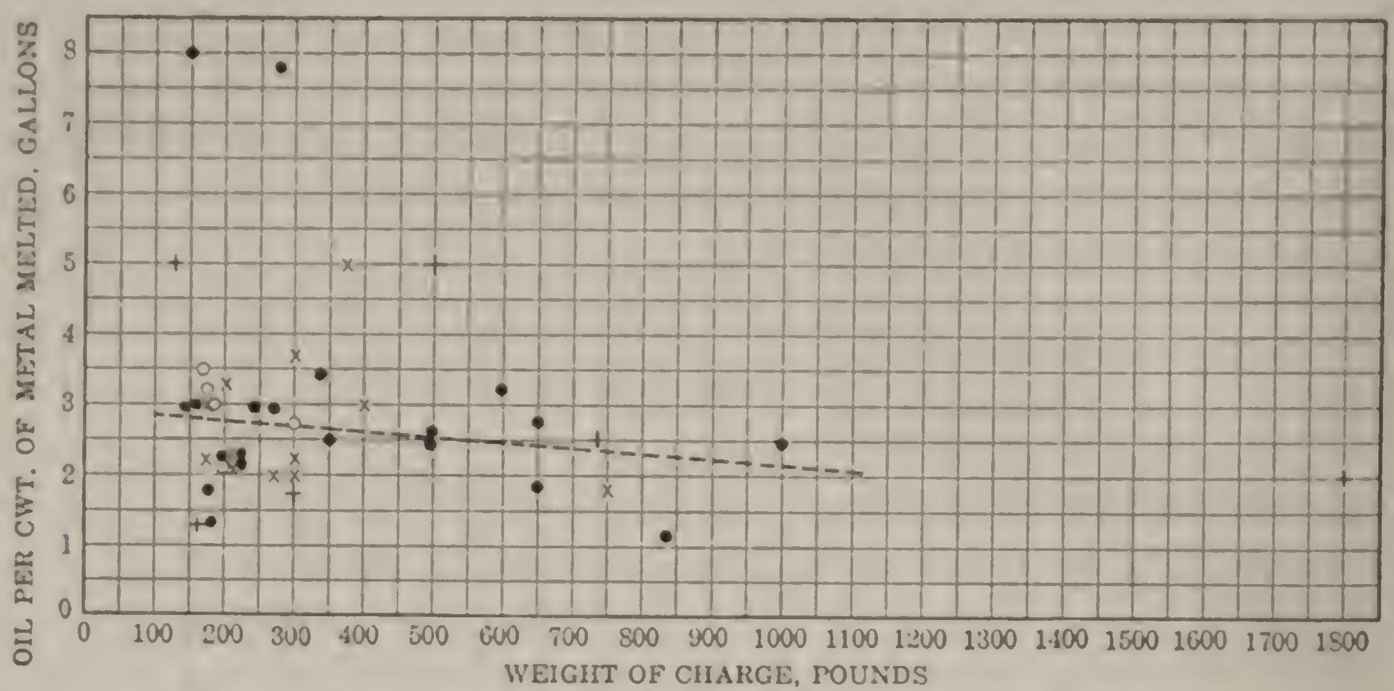

FIGURE 18.—Relation between weight of charge and fuel consumption in crucible oil furnaces. ● low-pressure air burner, low-zinc alloys (subdivisions 16, 17, and 28 of large table); ○ low-pressure air burner, high-zinc alloys (subdivisions 18 and 19); × high-pressure air burner, low-zinc alloys (subdivisions 19 and 30); + high-pressure air burner, high-zinc alloys (subdivisions 20 and 31).

the way shown by the boiling-point curve in figure 2, it is seen that metal loss is on the whole better controlled on the high-zinc than on the low-zinc alloys when their relative volatility is compared.

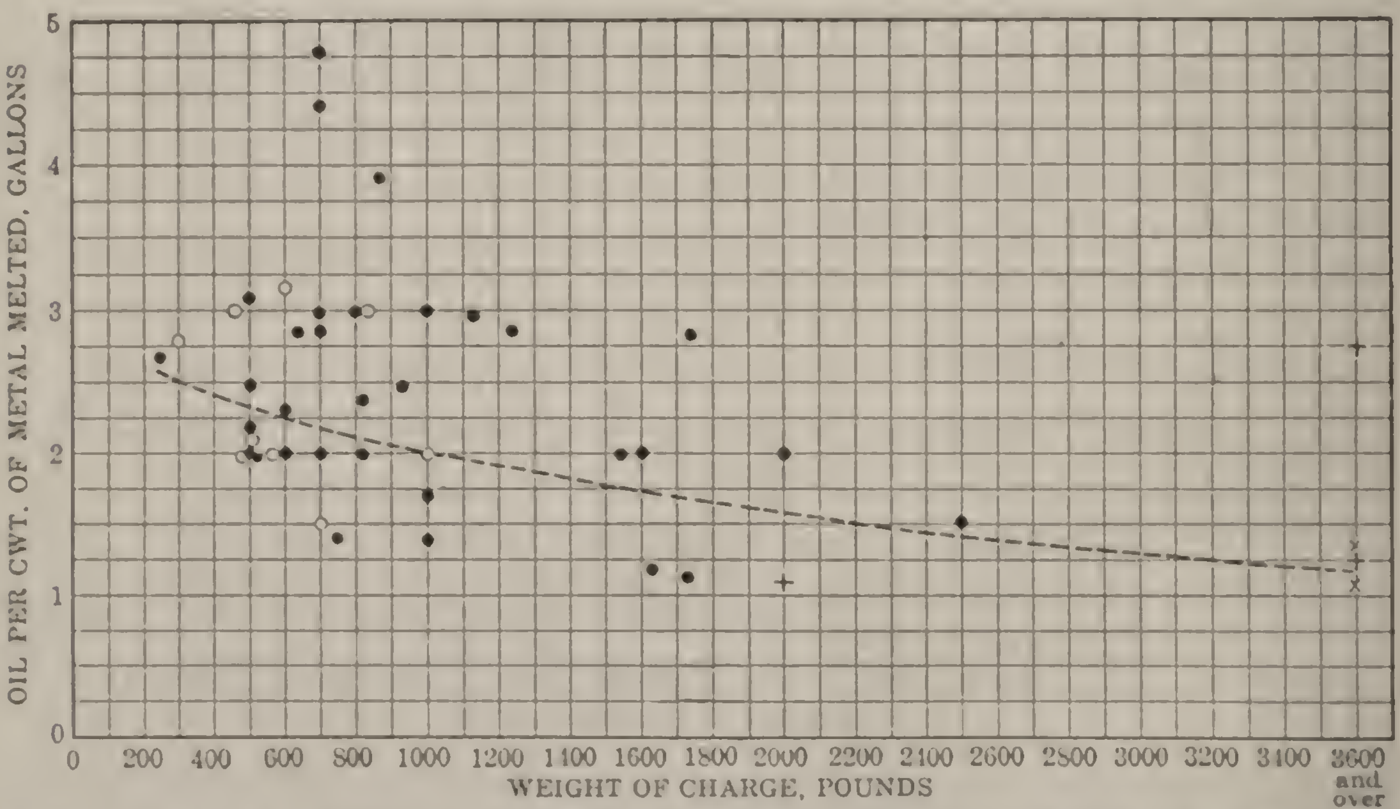

FIGURE 19.—Relation between weight of charge and fuel consumption in open-flame and reverberatory oil furnaces. ● open-flame oil furnace, low-zinc alloys (subdivision 32 of large table); ○ open-flame oil furnace high-zinc alloys (subdivision 33); + reverberatory oil furnace, low-zinc alloys (subdivision 36); × reverberatory oil furnace, high-zinc alloys (subdivision 37).

Hence no idea of the relative values of different types of furnaces can be formed from the averages of the data taken from so many

different plants working under different conditions. The general conclusion that the differences in the operation of a given furnace on a given alloy show more variation in fuel efficiency and melting loss than does the use of different types of furnaces on that alloy is justified by the data represented in figures 15 to 21. Therefore it is wise to place more reliance on the reports of tests of various types of furnaces on the same alloy and under the same working conditions in the plant than on the averages of the data reported.

Some of the features that are better brought out by the comments of the firms replying than by the averages of the data are discussed below.

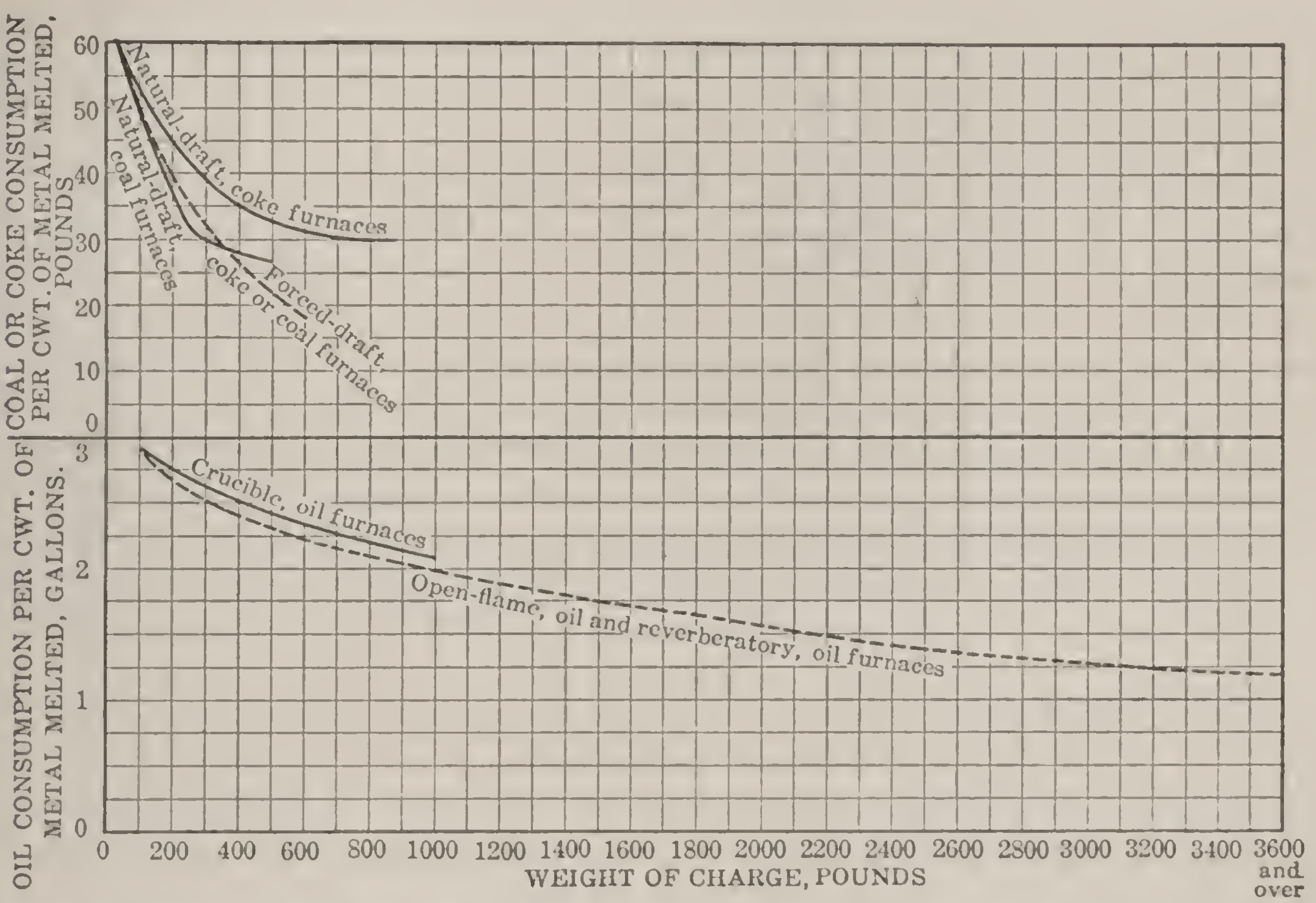

FIGURE 20.—Curves showing averages of data as to relation of weight of charge to fuel consumption in five types of furnaces. The curves do not necessarily represent the relative behavior of the different furnaces under strictly comparable conditions.

ROUND COMPARED WITH SQUARE, PIT, COAL OR COKE FURNACES.

Square, pit, coal or coke furnaces are used almost exclusively in rolling-mill practice, but rarely in ordinary foundries if the furnaces take a crucible smaller than No. 125. Above that size the square furnaces are the more common.

It is said that it is easier and cheaper to reline a square furnace than a round one, but with the present prices of circle brick or of complete circular sections this advantage can not be great. Another reason given is that it is easier to poke the fire in the corners of the square furnace.

Most of the users of square furnaces outside of the rolling-mill operators admit that fuel efficiency would be better in a round furnace. The main reason usually given for the use of the large square furnaces is that it is not possible to get the tongs down over the bilge

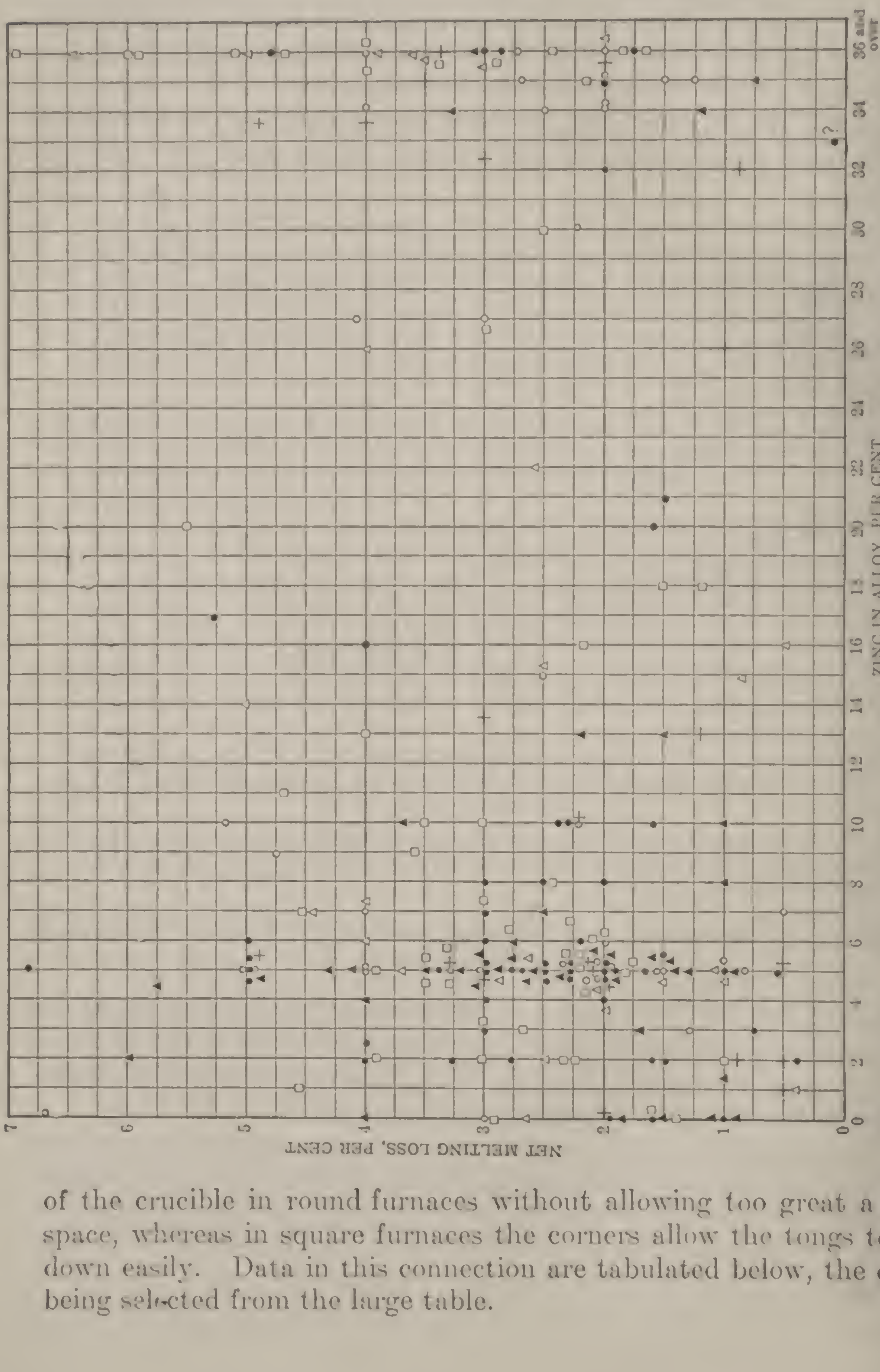

FIGURE 21.—Relation of net melting loss to zinc content of alloy melted: ● natural-draft coke furnace; ○ natural-draft coal furnace; + forced-draft coal or coke furnace; ▲ crucible gas or oil furnace, low-pressure air burner; △ crucible gas or oil furnace, high-pressure air burner; □ open-flame oil or gas or reverberatory oil or coal furnace.

of the crucible in round furnaces without allowing too great a fuel space, whereas in square furnaces the corners allow the tongs to go down easily. Data in this connection are tabulated below, the data being selected from the large table.

Data on round as compared with square, pit, coal or coke furnaces.

ROUND FURNACES.

Reply No.	Subdivision No.	Inside diameter or length of side.	Crucible No.	Outside diameter of crucible at bilge.	Fuel space.	Alloy melted.[a]	Fuel used.	Fuel per hundredweight of metal.	Crucible life.
		Inches.		*Inches.*	*Inches.*			*Pounds.*	*Heats.*
14	1	27	250	17	5	R. B	Coke	30	18
21	9	21	200	$16\frac{1}{2}$	$2\frac{3}{4}$	Y. B	Coal	33	25 to 35
24	12	22	200	$16\frac{1}{2}$	$2\frac{3}{4}$	Mn. Bz.	Coal and coke.	[b] 50	15
82	1	26	300	$17\frac{1}{2}$	$4\frac{1}{4}$	R. B	Coke	33	33
Average					$3\frac{11}{16}$			35.8	24

SQUARE FURNACES.

Reply No.	Subdivision No.	Inside diameter or length of side.	Crucible No.	Outside diameter of crucible at bilge.	Fuel space.	Alloy melted.[a]	Fuel used.	Fuel per hundredweight of metal.	Crucible life.
38	2	24	300	$17\frac{1}{2}$	$3\frac{1}{4}$	G. M	Coke		16
70	2	24	300	$17\frac{1}{2}$	$3\frac{1}{4}$	R. B	do	30 to 50	13
74	2	24	300	$17\frac{1}{2}$	$3\frac{1}{4}$	G. M	do	25	25
79	8	$22\frac{1}{2}$	200	$16\frac{1}{2}$	4	R. B	Coal	35	12
87	2	24	300	$17\frac{1}{2}$	$3\frac{1}{4}$	R. B	Coke	45	18
87	4	24	300	$17\frac{1}{2}$	$3\frac{1}{4}$	Mn. Bz.	do	[c] 50	
189	10	18		$15\frac{3}{4}$	$1\frac{5}{8}$	Y. B		32	40
201	2	22	250	17	$2\frac{1}{2}$	Pb. Bz.	Coke	35	18
Average					$3\frac{45}{64}$			37.8	20

[a] In this column R. B. signifies red brass composed approximately of 85 parts copper, 5 parts zinc, 5 parts tin, and 5 parts lead; Y. B., yellow brass, approximately 66 parts copper and 34 parts zinc, with or without a little lead; Mn. Bz., manganese bronze, approximately 56 parts copper and 41 to 42 parts zinc, with some iron, tin, aluminum, and manganese; G. M., Gun metal approximately 88 parts copper, 10 parts tin, and 2 parts zinc; Pb. Bz., leaded bearing bronze of, say, 78 parts copper, 7 parts tin, and 15 parts lead.

[b] Forced draft is used part of the time. Furnaces not pushed to full capacity.

[c] Most of the information supplied indicates that manganese bronze or other high zinc alloy required less fuel per hundredweight than red brass. Reply 87 is an exception.

Replies 189 and 201 are the only ones in which the square furnaces show less space between the bilge of the crucible and the nearest point of the furnace wall than the round ones, and the average space in the round furnaces is only one sixty-fourth inch less than in the square ones.

The fuel consumption shows no notable difference, though the average is in favor of the round furnace. However, Reply 6 states that in a forced-draft, tilting, coke furnace alteration from a square to a round form (maintaining the same volume of coke space) effected a fuel saving of 17 to 20 per cent.

Reply R states that in rolling-mill work actual experiment showed that round furnaces were distinctly more economical than square. The size and standing of the firm supplying this information entitle its opinion to great weight.

Reply 67 indicates the superiority of the round form.

Reply 79, though from a plant using square furnaces, states that round ones require less fuel and give a more even heat.

Reply 95, from a rolling mill, states that their experience is that the square furnaces give a lower fuel consumption.

Reply 110, on the other hand, states that round furnaces are better than square.

Sexton [a] says that it is obvious that round furnaces are better than square, whereas Bartley [b] says that the crucible life is better in round furnaces. Although the foregoing table is not conclusive on this point, the average is again slightly in favor of the round furnaces.

It would be worth while to try closing up two opposite corners of a square furnace into circular shape if it is felt that the other two corners are needed for admitting the tongs, to determine whether the fuel efficiency would not be increased. This arrangement should give half the advantage of a completely round furnace over a completely square one.

Bartley claims that crucible life is decreased when either too small or too large a crucible is used. This claim seems reasonable, but tabulation or plotting of the data received to show the relation between crucible life and fuel space does not give conclusive indication one way or the other.

RELATION OF COAL OR COKE SPACE TO FUEL EFFICIENCY.

It is obvious that the use of too large or too small a crucible in a furnace will decrease the fuel efficiency. Too large a crucible requires constant additions of cold fuel, chilling the fire as well as making a higher labor charge. Too small a crucible results in loss of heat between the furnace walls and the crucible. However, it is difficult to determine the proper fuel space, and here again tabulating or plotting the data received leads to no definite conclusion. It is necessary to fall back on the comments of firms who have performed properly regulated experiments.

Sexton [c] says that the layer of coke need not be thick, 3 or 4 inches being sufficient. Bartley [d] says that good foundrymen vary in opinion on this point, some preferring a 3-inch space and others a space as thick as 6 inches on a No. 60 crucible. Bartley's experiments were on a No. 70 crucible with a 4-inch fuel space.

A similar difference of opinion was found in talking with managers, superintendents, and foremen at the plants visited. The general evidence is that 3 inches on Nos. 40 to 100 and 4 inches on larger sizes is ample.

A fuel engineering company states, "In coke firing, the space between the crucible and the furnace walls should not be more than 3 inches for fuel economy."

There is considerable evidence to show that many furnaces in use have too large a fuel space, as a number of reports state that a larger

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[a] Sexton, A. H., Alloys, p. 2[illegible].

[b] Bartley, J., Crucible and furnace relationship: Metal Ind., vol. 11, 1913, p. 1[illegible].

[c] Sexton, A. H., loc. cit.

[d] Bartley, J., loc. cit.

crucible than is commonly employed can be used, with no more coke consumption for the larger charge than for the smaller, and that the heat takes no longer. The use of a larger crucible consequently means an improvement both in fuel consumption and speed of melting per hundredweight of metal melted. Examples of this are Reply 33, stating that less coke per heat is used in their furnaces for a No. 125 pot than for a No. 80, and Reply 140, which states that the firm represented uses progressively less fuel for a No. 80 and a No. 90 than for a No. 70.

Similar evidence is given by Reply 125, which states that when the furnace lining is new the fuel consumption is 25 pounds of coke per hundredweight, and that when the lining is worn thin, allowing greater coke space, 33 pounds is used. Reply 22 attempts to even up the average size of the furnace by making it taper slightly toward the bottom, thus perhaps having a little less coke space than is ideal at the first, and a trifle more near the end of the life of the lining.

On the whole, it appears that many users of pit coal or coke furnaces might find a distinct improvement in fuel economy and speed per hundredweight by using a crucible a size or two larger than they use ordinarily.

The height of the bed of fuel upon which the crucible is set in this type of furnace is important. One old furnace tender said, in conversation during the author's visit to his plant, that when with a thick fuel bed he had used 50 pounds of coke per hundredweight of metal on a No. 70 crucible of red brass, he had shortened the furnace (raising the grate bars and keeping the flue in the same position), thus obtaining a thinner bed and a fuel consumption of only 25½ pounds per hundredweight.

IMPORTANCE OF DRAFT IN NATURAL-DRAFT FURNACES.

Another feature of great importance in natural-draft furnaces is the strength of the draft. Few plants have any definite knowledge concerning this feature, as not half a dozen of the firms interrogated answered the question bearing on it, so that not enough data were collected to be of value. Some foundries that have a long row of pit furnaces on the same flue have so much variation in the draft between those nearest to and farthest from the stack that the nearer furnaces will get out a heat two-thirds quicker than will furnaces at the end. To remedy this variation, one rolling mill builds separate flues to the stack for each set of three furnaces, instead of allowing a dozen or more to run on the same flue. Natural-draft furnaces vary so much in strength of draft with the wind and with the humidity of the air that the length of any one heat is an unknown quantity. In general, the better the draft, the higher the fuel efficiency.

Rolling mills in general use higher stacks than foundries, and the better draft accounts in part for the better fuel efficiency and greater melting speed shown by rolling mills in general as compared with foundries melting the same alloys and using the same fuel.

The size of the fuel also influences the draft, too small sizes of coal or coke, or fuel with both large and small pieces, resulting in the filling of the openings between the large chunks by the smaller ones, impeding the draft considerably. The size and spacing of the grate bars also makes a difference in the strength of the draft.

FURNACE FUELS.

COMPARISON OF METALLURGICAL AND BY-PRODUCT COKE.

The bulk of the pit coke furnaces use 72-hour Connellsville coke; 48-hour Connellsville coke being second, and by-product coke finding only small use. At equal prices for hard Connellsville coke and for by-product coke at the foundry door, the hard coke is unquestionably cheaper. It will melt more metal per ton than the by-product coke, and requires less labor, as the by-product coke is less dense and burns faster, thus requiring more frequent firing.

Yet there are many foundries that pay high prices and high freight rates for metallurgical coke when by-product coke, obtainable near at hand, would be the cheaper fuel. The foundryman is accustomed to using metallurgical coke in his iron cupola, as there a strong coke is needed to support the charge, and he assumes that because it is the better for iron it must needs be the best for brass, whereas the two conditions are not comparable. Such problems must be solved by each plant according to the existing conditions.[a]

COMPARISON OF COAL AND COKE.

Hard coal is used by yellow-brass rolling mills almost to the exclusion of other fuels. The furnaces have not been notably improved in the past hundred years. Whether this fact is mainly due to the inherent advantages of the pit coal furnaces or to the natural conservatism of an industry that is highly localized and is in the hands of some 60 firms is a question. The furnaces are so proportioned that when the coal added at the beginning of the heat has been burned, the heat of metal is usually ready to come out, recoaling being rarely needed, resulting in lessened labor cost.

With alloys having higher melting points, the greater speed of melting with coke gives it a decided advantage, so that in ordinary foundry work, on red brass, for example, pit coke furnaces far outnumber pit coal furnaces.

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[a] See Dean, W. R., Coal vs. by-product coke in the brass foundry: Metal Ind., vol. 8, 1910, p. 461.

COMPARISON OF FORCED-DRAFT AND NATURAL-DRAFT COAL OR COKE FURNACES.

The users of forced-draft pit coal furnaces are mainly those who have found that natural draft would not give them the high temperature needed to pour metal for light work in any reasonable time, or who have copied the installations of earlier firms in their locality. Yet the advantages of forced draft even for pit furnaces are considerable. Although the construction of such a furnace is more expensive, and although a blower and power are required for its operation, the speed of melting is under vastly more efficient control, and a tall stack is not necessary. If the metal is hot enough to be poured, but the molds are not ready, the blast can be closed and the metal "held back" in a forced-draft furnace with less fuel consumption and less metal loss than in natural-draft furnaces, in which combustion is less readily retarded, and the temperature of the metal increases as long as the pot is in the fire. This advantage, of course, accrues also to gas or oil furnaces.

Tilting coke furnaces, which, of course, must be run under forced draft, show a vast increase in melting speed, crucible life, and fuel efficiency over pit coke furnaces of the same size. At present fuel prices the forced-draft tilting coke furnace probably gives the lowest fuel cost per hundredweight of metal melted in most localities, except the Pacific coast, of any type of furnace of no larger capacity except possibly the natural-gas or producer-gas furnace. Large open-flame gas or oil furnaces, even at the present price of fuel oil, and large reverberatory furnaces may, in many localities, still have an advantage in fuel cost, besides that of no crucible cost.

The main objection to tilting, forced-draft, coke furnaces for work for which a tilting or tapping furnace might be used, is that most makes are hard on the furnace tender, some users describing them as "man-killers." Unless put in a pit, as is done with one make, considerable lifting in charging and in the frequent coking is required. The furnace tender finds the heat around these furnaces greater than around almost any other type. Replies 74, 79, 81, and 180 agree on this feature.

The melting loss in this type is claimed by many to be excessive. For material low in zinc, the loss figures given in the large table (subdivision 13) for replies 79 and 152, the accuracy of both of which is unquestionable, should sufficiently controvert the idea that the furnaces can not be run without a high loss. Reply 79 (subdivision 15) also shows that in melting yellow brass for work that does not require a high temperature, their behavior, if they are properly handled, may be entirely satisfactory. The losses on high-zinc alloys cast at high temperatures as noted in the replies listed in subdivision 14 of the table

are higher than the loss shown by the best practice for some other types of furnace. Yet the figures on yellow brass or manganese melted in this furnace are so few that they should by no means be taken as proving that the zinc loss can not, with careful handling, be reduced to such a point that the over-all cost will not be less than that in other types if the favorable speed, crucible life, and coke consumption be considered.

These furnaces are also severely criticized on the score of gas absorption by the metal, many foundrymen claiming that it is impossible to make from metal melted in them castings that will stand pressure. However, one user is making a red-brass casting that must stand steam pressure, and be absolutely free from dross on a machined surface. Another is making a high-grade valve, and still another is making yellow-brass plumbing goods, and all are producing a high class of product.

For low-zinc alloys to be poured into heavy chunky work, like car bearings, their value is unquestioned, and even for more difficult work a foundryman who desires a high melting speed and is not able to get fuel oil at a reasonable price, or with reasonable certainty of prompt delivery, would do well to consider carefully the advantages of these furnaces.

LIQUID AND GASEOUS FUELS.

Natural-gas or oil crucible furnaces insure ease of control, cleanliness, freedom from handling fuel or ashes, great melting speed, long crucible life[a] when properly designed and operated, and such control of combustion as to make possible the maintenance of a reducing atmosphere. These advantages place the oil and gas furnaces far ahead of natural-draft coal or coke furnaces, except, possibly, when yellow brass or manganese bronze is to be melted.

Brasseur[b] cites tests on the same alloy (composition not given) which showed a tensile strength of 17,000 to 21,000 pounds per square inch and an elongation of 3 per cent when the alloy was melted in a coke-fired furnace, and a tensile strength of 33,000 to 38,000 pounds per square inch and an elongation of 13 per cent when the alloy was melted in an oil-fired furnace. Such a difference would, however, seldom be found. Brasseur gives the comparative melting losses as 2 per cent with coke and 1½ per cent with oil, and claims that this saving, as well as improved quality of product and a decreased labor cost, far overbalances the slightly increased cost of fuel when oil is used.

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[a] Although shorter crucible life is claimed by many for them than for natural-draft coal or coke furnaces, the averages of the data represented in figures 11 to 13 are in their favor.

[b] Brasseur, M., L'application du chauffage a l'huile lourde aux fours métallurgiques: Rev. de mét., vol. 10, 1913, p. 931.

Although excessive gas absorption in melting all alloys and excessive zinc loss in melting high-zinc alloys are claimed by their opponents to occur in the use of gas or oil furnaces, the bulk of testimony is that the quality of the metal produced is fully equal to that produced in the old-style pit furnace.

In cases like this, when a number of foundrymen state in good faith, but usually on the basis of short experience with oil or gas furnaces, that such furnaces can not be run to give as good results as the old-style pit furance, and when an equal or greater number, with vastly more experience with the newer furnaces, state that they can be run to give as good results and that they are daily being so run in their own plants, it is necessary to give more weight to the testimony of the foundrymen who can and do get good results than to the testimony of those who can not.

It must be granted that the speedier furnaces require a wider knowledge of combustion and more care on the part of the furnace tender. The natural-draft pit coal or coke furnaces have been used for a century and more, being a direct outgrowth from the Bronze Age and the days of calamine brass, and their operation has become well known, whereas the gas and oil furnaces have been in commercial use less than a score of years. However, the advantages of the use of liquid or gaseous fuel so far outweigh those of solid fuel that what they lack of being "fool proof" is more than compensated with the possible but by no means certain exception of their use on high-zinc alloys.

NATURAL GAS.

Of the liquid and gaseous fuels, natural gas, where it is available, deserves first mention as regards cheapness. For use in crucible furnaces on low-zinc alloys, natural gas, at the prices current in most natural-gas regions, shows high over-all economy. One drawback is the liability of the pressure in the pipe lines to drop badly in cold weather—a feature that has forced some plants to install an emergency oil system for use when the gas pressure fails.

Where oil can be had at a low price the greater speed attainable and the consequent decreased loss of zinc by volatilization have led most of the users of open-flame furnaces, particularly furnaces for alloys high in zinc, to prefer oil for fuel, even though natural gas was available. If the gas and air were both preheated it might easily be possible to increase the melting speed enough to offset the advantages of oil, particularly at the ruling prices. The figures reported for fuel consumption on natural-gas furnaces are not as good in comparison to other fuels as would be expected from the relative performance of natural gas in other lines of industry, so that its possibilities are probably greater than the reported results indicate.

CITY GAS.

City gas, on account of its general high price, has so far found little use in brass-melting furnaces. However, in some localities a low price is made for city gas for industrial use. Under such circumstances, particularly if the gas pressure be raised and both gas and air be preheated, it would approach natural gas in feasibility. Suggestion has even been made that brass melters doing a large volume of work might profitably install a small gas plant of their own, the lower labor cost at the furnace being considered enough to offset the installation and labor charges on the gas plant.

Another possibility that should be considered is the use of waste gas from by-product coke ovens. Such gas averages 500 British thermal units per cubic foot,[a] or 80 per cent of the calorific value of average city gas, and is said to be giving good service in open-hearth steel melting; it should rank between city gas and producer gas as regards melting speed and metal losses in brass melting. Becker and Robertson state that it is applicable for melting brass, but no figures on its operation are available.

PRODUCER GAS.

Producer gas, on account of its high nitrogen content and the relatively large volume of waste gases it produces, seems of doubtful value for open-flame or reverberatory furnaces, although its success in large-scale reverberatory furnaces for melting iron puts it in a more favorable light. Cold producer gas is out of the question, but with properly preheated gas and air, or perhaps the semiproducer type of installation, reverberatory furnaces are a distinct possibility for low-zinc alloys.

Hughes[b] speaks of a producer-gas reverberatory furnace having a capacity of 25,000 pounds as the furnace ordinarily used for refining red brass borings in English practice.

A fairly large installation of furnaces is essential to make the cost of installing and running a producer worth while.

On the whole, the use of producer gas for brass melting is still in the experimental stage in this country, although for the conditions of the plant furnishing the data in reply 164 (subdivision 26 of the large table) it has been a successful experiment.

Bulmahn[c] discusses fully the application of producer gas in a foundry making red-brass castings.

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[a] Becker, J., and Robertson, L. B., Production and industrial application of by-product coke-oven gases: Jour. Ind. Eng. Chem., vol. 5, 1913, p. 491.

[b] Hughes, G., Nonferrous alloys in railway work: Jour. Inst. Met. (British), vol. 6, 1911, p. 94; Castings, vol. 9, 1911, p. 13; Metal Ind., vol. 9, 1911, p. 426.

[c] Bulmahn, E. F., The application of producer gas to brass foundries: Trans. Am. Inst. Metals, vol. 7, 1913 (not yet published).

Producer-gas melting, with regenerative heating of gas and air, is also being tried in one rolling mill. Pit furnaces are used and the crucibles are not covered. The experiments have not yet gone far enough to be conclusive, but a fuel consumption of 35 pounds of a low-grade soft coal per hundredweight of yellow brass melted has been obtained. The coal costs only $2.25 per ton. No actual figures on melting losses are yet available, but it is stated that a comparison of the composition of the material charged with the composition of the metal obtained shows the loss to be the same as in coal or coke furnaces. This result applies both to yellow brass and to Muntz metal.

Therefore no gain as to melting loss is expected. That less handling of fuel is required and that the ash does not have to be treated for the recovery of metal are thought to give the use of producer gas at least an even chance with the ordinary type of furnaces. The metal from the producer-gas furnaces is stated to be of just as good quality for rolling as that from coal or coke furnaces.

A firm making gas producers reports that it attempted to apply producer gas to an open-flame brass furnace, but that the attempt was a total failure on account of excessive zinc losses.

For melting yellow brass or manganese bronze, producer gas is badly handicapped by its low heating value and high nitrogen content, so that naturally this experiment and those of the rolling mills on its use in reverberatory furnaces have not so far met with commercial success.

Waste blast-furnace gases of 90 to 100 British thermal units [a] are available in large volume in certain localities. Blast-furnace gas is said [b] to be of too low heating power to be useful for open-hearth steel melting, but such use is said to be feasible if it be mixed with one-third or one-fourth of its volume of waste gas from by-product coke ovens, a waste gas also available in some of the localities in which blast-furnace gas can be obtained. Such a mixture should stand on an even basis with producer gas, and, inasmuch as its components are wastes, should be cheaper where available. Gouvy [c] states that coke-oven gas is suitable for heating reverberatories, but that blast-furnace gas is hardly suitable for this purpose, although it is being tried in Germany.

FUEL OIL.

Fuel oil is of several varieties, ranging from the heavy California and Mexican crudes and the lighter Pennsylvania crudes (the crude

[a] Crabtree, F., Cheap power in the Pittsburgh district: Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 97; Thaler, H., Values of blast-furnace gases: Oest. Zeitschr. f. Berg- u. Hüttenwesen, vol. 61, 1913, p. 71; Chem. Abs., vol. 7, 1913, p. 2033.

[b] Becker, J., and Robertson, L. B., loc. cit.

[c] Gouvy, A., Utilization of blast-furnace and coke-oven gases: Engineering (London), vol. 94, 1913, p. 684; Jour. Ind. Eng. Chem., vol. 5, 1913, p. 255.

may or may not be partly freed from sulphur) through "residuum," which is a residue after the light oils, such as gasoline and kerosene, have been distilled off,[a] to a light product obtained by distillation. This is stated[b] to be giving good results for crucible-steel melting. On the other hand, the catalogue of a maker of open-flame furnaces contains the following statement:

> If the grade of fuel oil known as distillate is used (which may consist of gasoline or benzine residues), 4 or 5 gallons may be required to melt 100 pounds of brass—more than double the amount usually used. The loss from volatilization with such an oil is high, and on account of its low gravity the weight per gallon is less than with an oil of higher gravity.

Sherman and Kropff[c] find that, although the calorific value per pound decreases as the specific gravity increases (or as the degrees Baumé decrease), the variation in density more than compensates for the increase, so that the heavier the oil the higher the calorific value per gallon.

The oils covered by reports of firms replying to the list of questions do not show any very great variation in heating value, and, speaking broadly, the fuel oils used in foundry practice do not show as much variation between samples from different sources as do coal or coke samples from different sources.[d]

RISE IN PRICE OF FUEL OIL.

In 1911 fuel oil was obtainable in many localities at 2 to 3 cents per gallon. In the early months of 1913 the price was, in general, 5 to 7 cents, and in some cases up to 10 cents or more, but in the later months it fell to 4 to 5 cents. Coupled with the change in price has come an uncertainty in delivery. In certain sections of the Middle West the main producers of oil have refused to enter into contracts for delivery of oil either at stated intervals or stated prices. The firm furnishing Reply 43 is putting in more furnaces, but is installing coal furnaces in preference to oil furnaces, on account of the price of fuel, although the oil furnaces are to be kept in use. Replies 5, 71, 79, and 197 also show the effect of the increase in price.

This increase in price has also created a demand for a furnace that can be speedily altered from the oil-burning type to one burning coke or coal, so as to be ready for production if the price of oil rises so far as to prohibit its use with that fuel. The rise in oil has given a decided setback to the makers of oil furnaces and oil burners. Furnace users are inclined to sit by and see what developments occur

[a] Waterhouse, G. B., Liquid fuel and its application to the foundry: Metal Ind., vol. 5, 1907, p. 259.

[b] Editorial, Substitute for fuel oil: Foundry, vol. 41, 1913, p. 251.

[c] Sherman, H. C., and Kropff, A. H., Calorific power of petroleum oils and the relation of density to calorific power: Jour. Am. Chem. Soc., vol. 30, 1908, p. 1626.

[d] Robinson, F. C., Manufacture of petroleum products: Met. Chem. Eng., vol. 11, 1913, p. 389.

in the oil market before changing from some other fuel to oil. It is not the present high price that deters them so much as the uncertainty of deliveries and the fear that the price has not reached a stable figure.

The price of coal and coke has, in general, risen also, so that the percentage increase in the price of oil over anthracite or coke is not so great as its own percentage increase in price.

That so few melters of brass have abandoned oil furnaces during the period of increase in price is the best testimony as to their value for the purpose.

Sperry [a] states that, in spite of the doubling in price of fuel oil, plants are constantly being equipped with oil furnaces for melting and annealing, and deduces that the fact that users have stood a 100 per cent increase in price shows that there are greater advantages in oil furnaces than has been generally admitted. However, the higher cost, together with the increase in the prices of copper, tin, and zinc over those of 1911, has stimulated interest in the study of brass furnaces, both as regards fuel efficiency and metal losses, and in the use of electric furnaces for melting brass.

The reasons for the increase in the price of oil are variously ascribed to increase in the consumption, particularly of the gasoline and lubricating oil fractions, over the supply and to trust action. It seems likely that to some extent, at least, the rise reflects the condition that the value of refined products that can be made from the oils previously used as fuel so far overbalances the cost of production that it is an economic loss to use the oil for fuel purposes at the prices formerly obtained.

In this connection Finney [b] makes the following statement:

> The waste in the petroleum industry comes principally from its wrong utilization. In the face of the approaching exhaustion of our petroleum industry, it would be well to limit the use of petroleum to the purposes for which it is necessary and for which no substitute can be found. It is for this reason that it can well be said that the use of nearly 19,000,000 barrels of crude oil burned as fuel in locomotives in 1907, at a price which brought not more than a hundredth part, and perhaps as low as a thousandth part of its value for high-grade petroleum products, and also our tremendous export business in oil, are serious economic mistakes.

One steel foundry has changed from oil to producer-gas fuel on account of the scarcity and high price of oil.[c]

That the problem of the fuel-oil supply is serious is shown by the appointment of a committee by the American Society of Mechanical Engineers to compile data as to the relative merits of fuel oil as

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[a] Sperry, E. S., Fuel oil and the brass industry: Brass World, vol. 9, 1913, p. 191.

[b] Finney, J. H., Conservation of natural sources of power: Trans. Am. Electrochem. Soc., vol. 17, 1910, p. 61; see also Day, D. T. (In discussion): Trans. 7th Int. Cong. App. Chem., 1910, p. 102.

[c] Anon., Improvements at the plant of the Falk Company: Foundry, vol. 41, 1913, p. 325.

compared with other fuels for various purposes, with the ultimate view of conserving its use as much as possible for those industries in which it has marked advantages over other classes of fuel.

The rise in price will result in curtailing the use of fuel oil for purposes for which some other fuel is really better adapted, but it hardly seems that brass melting falls in that category.

Whether the development of the Mexican oil fields, concerning which Best [a] is optimistic, and the increased availability of the California oil through the opening of the Panama Canal will relieve the situation remains to be seen. It hardly seems likely that the price will soon fall to the 1911 level, and the possibility of even higher prices can not be overlooked.

The advantages of oil fuel are such that the call for it will probably result in fuel oil of some grade being available, even though at high prices, for brass melting. Deliveries have been better in 1913 than were expected late in 1912.

The Mexican and California oils, in localities to which freight charges are not excessive, will seemingly come into wider use. In this event existing types of burners must either be modified to handle these heavier, more viscous oils, or the oils must be preheated before passing to the burner. Preheating [b] is common on the Pacific Coast, and will doubtless be more widely done as the density of the oil available increases.

Irish [c] makes the following statement:

> The supply of fuel and gas oils must necessarily be a function of the crude-oil production of the world. While the amount of crude oil produced has within the past few years been greater than at any other time since the discovery of petroleum, and consequently indicates an ever-increasing supply, we are at present, and have been for the last two or three years, suffering from a falling off in our production. We are informed that the crude-oil stocks in the United States, east of the Rocky Mountains, are decreasing at the rate of about 40,000 barrels a day.
>
> That means that the supply has fallen off and the demand has increased, until the demand has overtaken the production, and we are drawing on accumulated stocks, and, so long as that continues, exhaustion of the supply of gas and fuel oil will, of course, come nearer.
>
> But the supply of those oils has been supplemented by the Mexican crude. * * * The Mexican crude is new to the refiner, and it would be unsafe and unwise to predict what can be made from it. We know it has an asphalt base, and is limited in possibilities for the production of refined products. It means that a large production of such crude oil will find its way into the fuel-oil market as rapidly as it can be brought into this country.

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[a] Best, W. N., The science of burning liquid fuel, 1913, p. 18.

[b] Best, W. N., op. cit., p. 39.

[c] Irish.—(In discussion): Met. Chem. Eng., vol. 11, 1913, p. 394.

TAR.

Coal tar, water-gas tar, and oil tar form possible fuels for brass melting and have a higher heating value per gallon than fuel oil,[a] but their extreme viscosity makes their atomization more difficult. Preheating is vital, and the form of the burner must be such that the particles of solid carbon in the tar will not clog the burner. It is said[b] that both coal tar (undistilled) and tar oil have been successfully used in open-hearth steel furnaces. Coal tar has been used for crucible-steel melting, but no actual use seems to have been made of it for brass melting.

Oil distilled from coal tar would be similar to ordinary fuel oil for foundry use. No actual use of this on brass in the United States is known, but Dahm[c] describes pit and stationary-crucible furnaces, as well as a reverberatory, in which this oil is used in Germany.

REMARKS ON FURNACE TYPES AND FURNACE PARTS.

NATURAL-DRAFT OIL FURNACES.

Although the natural-draft oil furnace is common in crucible-steel melting, its use on brass was reported by only one of the firms that supplied data (Reply 198, subdivision 23, of the large table). The results reported are extremely favorable as to oil consumption and furnace life, unfavorable as to crucible life, and fair as to labor cost and loss of metal (red brass) in melting. The melting speed reported is slow, being 2.7 hours per heat on No. 40 to No. 100 crucibles, a rate that would mean a higher relative loss on a high-zinc alloy. This type of furnace makes hot work for the furnace tender. The oil-consumption figures given in this reply are the lowest reported for any type of oil furnace. However, as this type of furnace is well known from its wide use for melting crucible steel, if its advantages were in general as great as they seem to be in the particular plant in question, the furnace would probably have met with wider use.

ATOMIZING BURNERS FOR OIL.

In all other furnaces in which oil is used, some type of atomizing burner is utilized. There are four main types of burners: First, those atomizing the oil with steam, air for combustion being supplied by a low-pressure blower, or, more commonly, drawn in by the injector action of the spray; second, those accomplishing atomization by the use

[a] Best, W. N., Production of and demand for liquid fuel: Metal Ind., vol. 7, 1909, p. 101. The science of burning liquid fuel, 1913, p. 18.

[b] Hamor, W. A., Tar as fuel for open-hearth furnaces: Jour. Ind. Eng. Chem., vol. 5. 1913, p. 252; Hausenfelder, R., Coal-tar oil in the foundry: Gas World, vol. 59, 1913, p. 21; Chem. Abs., vol. 7, 1913, p. 3659.

[c] Dahm, A., Neuere Fortschritte und Erfahrungen in der technischen Verwendung der Teer produckte für Heiz-Kraft-und Lichtzwecke: Zeitschr. angew. Chem., vol. 25, 1912, p. 2049.

of a stream of compressed air at high pressure, which strikes a stream of oil fed at low pressure within the nozzle of the burner, forcing the oil through a small orifice, atomizing it, and mixing the spray or vapor with the air. Much of the air for combustion is thus supplied through the burner itself; the rest is drawn in by injector action. The third type (a combination high and low pressure type) forces the oil through an orifice at high pressure, and completes the vaporization by the least possible volume of high-pressure air, and supplies the air for combustion at low pressure (about 6 ounces). One form of burner has one opening for oil, which is fed at a rather low pressure, and another for high-pressure air, the streams meeting outside the orifices, and thus atomizing the oil into a fan-shaped spray. About one-sixth of the air needed for combustion is thus supplied, the rest being furnished at a pressure of 3 ounces through still another orifice below the burner.

Another form of this type allows a small volume of high-pressure air to meet, within or at the tip of the burner, a stream of oil which is partly vaporized by its own pressure (about 30 pounds) as it is forced from the orifice, the vaporization being completed by the high-pressure air. A concentric tube carrying air for combustion surrounds the rest of the burner.

In the fourth type, the high-pressure oil, low-pressure air type, the oil is vaporized by being forced through a small orifice solely by its own pressure, which is usually raised by pumping to about 45 pounds. Air for combustion is supplied, usually by a concentric nozzle, at a pressure of about 6 ounces.

It must be remembered that in boiler firing with oil, what is wanted for fuel efficiency is complete combustion of the oil; in brass furnaces what is desired is complete combustion of the oxygen of the air, so as to maintain a neutral or reducing atmosphere within the furnace, combined with as good fuel efficiency as can be obtained without getting an oxidizing flame. Hence it is desirable that the vaporization of the oil be accomplished with the minimum volume of air, for if in attempting to regulate the flame to obtain somewhat rapid heating, the ratio of air to oil can not be held to such limits as to avoid an oxidizing flame and still to supply enough well-vaporized oil, trouble will result.

If the burner is mounted in the open air and shoots the flame through a wide opening in the furnace wall, without any sort of damper to control the air drawn in by the injector action of the flame, the air supply, particularly if the ratio of oil to atomizing air is also not under sufficient control, may not be sufficiently under control, so that it may be difficult to maintain a reducing flame and still get proper atomization.

Whatever be the type of burner, absolute steadiness[a] of both oil and air pressure is essential; otherwise the flame fluctuates up and down, at times giving an oxidizing atmosphere and at times one so strongly reducing that fuel efficiency is out of the question.

STEAM ATOMIZATION.

In stationary and locomotive boiler practice, steam is commonly used for atomization because it is readily available, and its use does away with the need of an air compressor. However, the volume of steam required is considerable. The Naval liquid-fuel report states[b] that 5 per cent of the steam raised is used for atomization in this type of burner. At one copper smelter, the steam for atomization is given as one twenty-eighth of that raised.[c]

Redwood[d] gives an example of a burner that used 3 per cent of the steam for steam atomization, or 2 per cent to run an air compressor when the burner was working on compressed air.

Mathewson[e] states that in a copper furnace, a burner using air to atomize the oil has given better results than the burners using steam.

Best[f] gives the total net saving by the use of compressed air instead of steam as 4 per cent.

It is stated[g] that for very viscous fuels burners using steam are preferred because a sufficiently high pressure to vaporize the viscous material is obtained, but that burners using air show a higher economy.

Inasmuch as the use of steam introduces into the furnace just so much more gas to be heated, burners using steam are not, in general, as desirable as the other types.

The Naval liquid-fuel report,[h] made in 1904, states a preference for compressed air as compared with steam, and states that low-pressure air burners appear to be somewhat more satisfactory for marine purposes than burners using high-pressure air, although the matter was not then considered settled. Redwood,[i] however, in 1910 states definitely that for marine purposes atomizing the oil by forcing it through an orifice under its own pressure, without the use of steam or air as an atomizing agent, is best.

Only one foundry (Reply 61, subdivision 31 of the large table) has reported the use of steam as an atomizing agent. The oil consumption (which does not take into account the fuel used for steam

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[a] Best, W. M., The science of burning liquid fuel, 1913, p. 30.

[b] Report of the United States Naval Liquid Fuel Board, 1904, p. 318.

[c] Mineral Industry, 1911, p. 216.

[d] Redwood, B., Liquid fuel: Trans. 7th Int. Cong. App. Chem., 1910, p. 82.

[e] Mathewson, E. P., Development of the reverberatory furnace for smelting copper ores: Trans. 8th Int. Cong. App. Chem., 1912, vol. 3, p. 123.

[f] Best, W. M., The science of burning liquid fuel, 1913, p. 26.

[g] Anon., Firing with coal tar and water-gas tar: Gas World, vol. 58, 1913, p. 674; Chem. Abs., vol. 7, 1913, p. 2674.

[h] Report of the United States Naval Liquid-Fuel Board, 1904, p. 373.

[i] Redwood, B., op. cit., p. 72.

raising) is favorable in this case, but the single instance should not be taken to prove any superiority of steam atomization, in the face of the facts above cited.

BURNERS USING HIGH-PRESSURE AIR.

Burners using high-pressure air seem far less capable of easy regulation of the flame to different intensities, with the maintenance of a reducing flame, than either the combination, or the low-pressure types. All crucible oil furnaces that have been found unsatisfactory as to quality of metal produced seem to have been equipped with burners using high-pressure air. There has recently been a strong tendency among foundrymen to adopt the low-pressure or the combination type of burner in place of the burner using high-pressure air. Replies 3, 10, 14, 20, 37, 75, 78, 81, 102, 187, and N all represent firms that have either run comparative tests of these types, or have changed from a system requiring high-pressure air to one requiring low-pressure air, and all are strongly against the burner using high-pressure air. Not a single instance is known in which a user of the low-pressure or the combination type has changed to the use of high-pressure air.

It is cheaper to supply the needed air at low than at high pressure, both as regards the power required to run a compressor in comparison with that required to run a low-pressure blower, and as regards the cost of the compressor as compared with that of the blower. Of course, most foundries have a compressor for use with air-operated molding machines, air chippers, sand blasts, etc., but the compressor is seldom of such a capacity that it can handle the intermittent load from these sources and also carry a steady pressure for the furnaces. This practice results in a varying pressure at the burner, a varying flame, and difficulty in maintaining the proper reducing flame. Blowers are so cheap that they may be installed for each furnace or each few furnaces, which thus have a steady air supply.

It is noteworthy that practically all successfully operated open-flame oil furnaces, and most of the reverberatories, use comparatively low-pressure air and high-pressure oil.

Schutz[a] states that down to the point at which not enough air was supplied for combustion the zinc loss from an open-flame furnace was progressively decreased as the air pressure at the burner was lowered.

In a paper read before the Verein Deutscher Giessereifachleute, Lennings[b] advocates the use of a burner taking air at a pressure of

[a] Schutz, F. H. (In discussion): Trans. Am. Inst. Met., vol. 6, 1912, pp. 195, 196.

[b] Lennings, P., Oelfeurung, System Buess: Giesserei Zeit., vol. 10, 1913, p. 301.

about 7 pounds, but in the discussion on the paper, Felder vigorously opposed the use of high-pressure air.

Most burners using high-pressure air are very noisy, whereas both the combination and the types using low-pressure air are far more quiet. One maker claims to reduce the noise of the high-pressure type by pointing the oil burner downward at a slight angle on a bed of coal or coke that is used in conjunction with the oil. No information has been received as to the performance of furnaces using both solid and liquid fuel.

COMBINATION BURNERS.

Few foundries are known in which the combination burners are used, Reply 10 and Reply 134 (subdivisions 28 and 16 of the large table) being examples. Both the burners in the foundries mentioned are homemade. A similar one is on the market, but its sale for brass melting has not been pushed. The makers write:

> Our furnace development has been along the line of heating furnaces rather than melting furnaces. We have installed some brass-melting furnaces using oil, but have never had a very great success.

The oil consumption reported in Reply 10 (3 gallons per hundredweight) is rather higher than the average, whereas that reported in Reply 134 (1.3 gallons) is so far below it as to need verification by other users.

There is no question but that, with oil supply, atomizing air, and air for combustion all under control, and much of the atomization performed by the oil pressure, the nature of the flame can be controlled to a nicety with this type of burner. It requires an oil pump, a compressor, and a blower, or one more piece of apparatus than is required by the type using high-pressure air or by the type using low-pressure air. It is unquestionably a better type of burner than that using high-pressure air. Whether the extra regulation due to the three controls, as compared with two on the type using low-pressure air, justifies its use in preference to the latter is questionable, but if not as good, it runs a close second to the latter type.

In one type of burner the spray of oil coming through one orifice is met by a stream of high-pressure air outside the burner and thus volatilized, the oil vapor being then mixed with a third stream of low-pressure air. This type, although largely used for purposes other than brass melting, has some advantages and some disadvantages. It is more applicable to very heavy oils, or tar, and is less liable to be clogged by dirt in the oil or carbon in the tar than is the concentric form. However, it gives a fan-shaped spray instead of a conical one. The burner is not advocated by the maker for a furnace taking only one crucible, but is considered more applicable

to a large pit furnace containing several crucibles. This burner had been used in one plant visited, but had not, however, proved satisfactory. The heats were said to be slow, the furnace hard on the furnace tender, and the flame so oxidizing as to score the crucibles deeply. There was no way to tell whether the fault lay in the furnace, the burner, or the operation.

BURNERS USING LOW-PRESSURE AIR AND HIGH-PRESSURE OIL.

It is cheaper in power cost to atomize oil by pumping the practically incompressible oil and to supply air at low pressure than to atomize the oil and supply air for combustion by high-pressure air.

It is desirable to run the burner into the furnace, not through a mere opening in it, an arrangement that allows an unregulated volume of air to be drawn in by injector action; the burner should preferably run into a mixing or precombustion chamber of some design, the air for combustion being supplied by the blower. This may be under regulation, or else a damper or shutter may be provided at the opening, so that the air drawn in may be regulated by it. With such a device both air and oil are under good regulation and the nature of the flame is completely under control.

The averages of the data reported for the low-pressure air type do not show any striking difference in metal loss, crucible life, or oil consumption over those for the high-pressure air type, but the comments of the users who have tried both types go to show that with either the combination type or the low-pressure air, high-pressure oil type, gas absorption and oxidation being less, the quality of the metal obtained is better than with the high-pressure air type and the speed of melting is as favorable, oil consumption as low, metal loss less, and crucible life longer.

In classifying high-pressure air and low-pressure air burners the dividing line has arbitrarily been taken as a pressure of 2 pounds per square inch, although even with this pressure the burners are rather noisy.

Reply 20 states that burners using a 4-ounce air pressure are better than those using a 16-ounce pressure. The most representative forms of low-pressure air burners take air at 4 to 8 ounces and oil at 45 pounds or more. Several of these have followed rather closely the form devised by the United States Naval Liquid-Fuel Board [a] in which a helix just back of the orifice gives a whirling motion to the oil and aids in its atomization. Reply 187 describes a homemade burner of similar form, in which a drill is used to produce the whirling motion. A high oil pressure is desirable in order to produce a fine mist of oil, which will offer the greatest

[a] Report of the United States Naval Liquid-Fuel Board, 1904, p. 325.

possible surface per unit volume of the liquid oil. Unless the mist is fine and the oil thus well mixed with air, it is impossible to get sufficiently complete combustion to give a reasonably favorable fuel efficiency without using a large excess of air and thus producing an oxidizing atmosphere.

The United States naval liquid-fuel report of 1904 previously mentioned gives an extended classification and description of various forms of oil burners. Redwood [a] also describes several forms and Strohm [b] shows some used in boiler practice.

COMBUSTION SPACE.

An oil flame like that of a Bunsen burner is cold near the burner and reaches the maximum temperature near the outer tip. With most high-pressure air burners the flame is longer and narrower than with most of the combination or the low-pressure air burners, so that the hottest part of the flame may be well up toward the top of the crucible. The flame from a burner using high-pressure air often runs a foot or so above even a small furnace, whereas in the combination burner or the burner using low-pressure air it does not run out so far and fills the whole furnace chamber more completely.

Whatever be the type of burner ample combustion space is needed. The oxygen must diffuse in through the gases of combustion from the burning of the outer layer of each tiny droplet of oil before the remainder of the drop can be burned. Hence a certain time is needed for combustion. Burners using high-pressure air tend to carry the oil out of the furnace before this time has passed. An attempt is often made to break up the long flame by directing it on the sharp edge of a pear-shaped crucible block, or by placing an iron rod in the path of the oil spray as it leaves the burner and before it enters the furnace. As the hollow cone of mist from the burner using low-pressure air and high-pressure oil is wide, and as the air entering is at low velocity both space and time for combustion are given, so that fairly complete combustion may be attained without the use of too much air.

Too large a combustion space means a larger furnace, and more wall surface from which heat is radiated, so that there is a limit to the size. With too wide a furnace chamber the hot gases can not all come into contact with the crucible, so that a large part of them pass out without doing much good.

All sorts of devices are used to increase the time that the flame or hot gases remain in contact with the crucible or to lengthen their path about the crucible. The burner may be introduced tangentially,

[a] Redwood, B., Liquid fuel: Trans. 7th Int. Cong. App. Chem., 1910, p. 72.

[b] Strohm, R. T., Burners for oil fuel: Electrical World, vol. 62, 1913, p. 342; Chem. Abs., vol. 7, 1913, p. 3222.

a desirable arrangement, as it tends to produce a gyrating flame which passes about the crucible instead of merely upward along its walls.

Crucibles with a flaring flange at the top or a cover ring with an extending flange have been suggested. Such a flange would reflect the hot gases downward when they struck it and thus lengthen their path. Means for directing the flame against a serrated crucible block to break up the flame is another device, or the furnace lining may be serrated for the same purpose. It is hard to find refractories that will not become covered with slag, thus smoothing the surface and obliterating the serrations. A construction in which the burner is at the bottom of the furnace, pointing upward, so that the flame impinges on a crucible block properly suspended and with its lower surface spherical has been suggested as a means of breaking up the flame.

Many forms of baffles between the flame and the crucible, or between the crucible and the furnace wall, have been suggested, and some of them are in successful operation. The furnace chamber is sometimes enlarged at one side, so as to be pear shaped in plan, with the burner at the top and the crucible placed in the center of the circular part of the "pear," thus leaving a combustion chamber at the side of the furnace chamber. The flame shoots downward at the side of the crucible to the bottom of the furnace and then upward along the other side of the crucible. Then, too, the chamber may be oval, with a downward-pointed burner at each side.

Another form of furnace is approximately the frustum of a cone, with the larger chamber at the bottom (see note on Reply 103). Perhaps the form that is more widely used is an upright, cylindrical furnace chamber for the crucible; at right angles to this, and entering at the bottom of the furnace, is a shorter precombustion or mixing chamber, in which the oil and air are mixed, the flame as it reaches the furnace chamber proper being at a fairly high temperature, whereas that part of the flame in the mixer is not very hot.

This is a convenient method of lengthening the combustion chamber. Another step toward increase in length is the use of a taller and narrower crucible than the common form. The tall crucible is commonly used in tilting furnaces, and its use is one factor in the improvement in fuel efficiency of tilting over pit furnaces.

Redwood [a] (speaking of boiler practice) emphasizes the need of an ample combustion chamber, as follows:

Whatever system of atomizing may be adopted, the construction of the furnace is of the highest importance, and it is especially needful that there should be a combustion chamber of ample size, so that the combustion may reach the stage of the conversion of the carbon into carbon monoxide before the flame comes into contact with

[a] Redwood, B., Liquid fuel: Trans. 7th Int. Cong. App. Chem., 1910, p. 92.

cooling surfaces. It is also essential that there should not be an excess of air supplied to the furnace, for, whereas a little smoke may mean the loss of only 1 per cent of the heat-giving power of the fuel, an excess of air may easily cause 10 times this diminution in heating effect.

SQUARE OIL FURNACES.

The use of square oil or gas furnaces taking a single crucible is rare, although square furnaces are used at some of the mints. There can be no advantage in a square combustion chamber over a round one, and such a construction gives a greater shell area for radiation. The two square, pit, oil furnaces covered in the data given in subdivision 17 of the large table show about three times the normal oil consumption, but such a great variation is not to be ascribed to the shape of the furnace alone, although that is one of the factors causing the low fuel efficiency.

OPEN-FLAME FURNACES.

There is no one detail relating to brass furnaces on which there is so much and so marked diversity of opinion as on that of the quality of metal that can be obtained from open-flame furnaces.

Foundrymen are usually either rabid opponents or violent partisans of this type of furnace. The brass industry is divided into two camps; one considers open-flame furnaces unutterably bad, and the other swears by, and not at, them.

The discussion is still raging, as may be seen by comparing Best's point of view with that of Parry. Best [a] says:

> For a number of years oil has been used for the melting of brass and kindred alloys, but unfortunately direct-fired oil furnaces were recommended for this purpose, which resulted in the alloys, which melt at a lower temperature than copper, being sacrificed, thus causing an irreparable loss in metal, to say nothing of the attendant change in the composition of the metal. It was indeed a sad day when crucible furnaces were discarded for the direct-fired furnace; but now, thanks to the ability and fighting qualities of young metallurgists in (or who should be in) every brass foundry, we are again returning to crucible melting furnaces.[b]

Parry [c] takes the opposite view and states:

> For the past 10 years at least war has been waged between the believers in the open-flame furnace and those opposed to its use for the melting of bronze. * * *
>
> There is no trick in getting good results with the open-flame furnace, and anybody with a modicum of common sense and whose prejudice in favor of the antiquated crucible furnace is not so strong that it will curdle milk can get them. * * * When you get right down to "brass tacks," the cost of melting metal with fuel oil in an open-flame furnace is so small when compared with crucible furnaces that by its use you will save so much money that you can well afford a trip to Philadelphia to laugh at the mint.

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[a] Best, W. N., The science of burning liquid fuel, 1913, p. 130.

[b] See also Palmer, R. H., Foundry practice, 1912, p. 277.

[c] Parry, W. H., Brass-foundry furnaces: Metal Ind., vol. 11, 1913, p. 423.

The number of replies explicitly approving and the number condemning the open-flame furnace are of about equal number, although many merely report the almost exclusive use of this type, thus tacitly approving it.

Many foundrymen, after a somewhat extended trial, have thrown this type of furnace out on the scrap pile, from which it usually is rescued by some other foundryman who likes the type. One plant using six of this type had to buy only two from the maker, getting the other four from his competitor's scrap piles.

With such a conflict of honest opinion, it is of interest to determine why those who failed did fail, and why those who succeeded did succeed.

Eliminating the instances where the cause of failure was that the castings made required such hot metal that the loss of heat due to pouring the metal into a ladle made it impossible to use a ladle, a condition that would count equally against a tilting-crucible furnace, it appears that, without known exception, the probable cause of failure on red brass or any low-zinc alloy was operating this type of furnace under oxidizing conditions, or at too slow a speed; every success was probably due to operating the furnace under reducing conditions and at a rapid rate.

The open-flame furnace is not fool-proof. It demands such a burner and such oil and air pressure as will allow the use of a reducing flame, and probably one considerably more reducing than will answer in a crucible furnace. It is essentially a high-speed furnace, and should be run as such.

As the flame is directly over the metal, which has a greater surface per unit volume than in crucible types, the opportunities for gas absorption and for zinc volatilization are great. However, owing to the fact that the heating surface is large and that the heat does not have to pass through a crucible to get to the metal the speed is also great. If the furnace is operated with a burner giving a suitable reducing flame and one that will yet burn oil enough to develop sufficient heat, and if the metal is promptly poured as soon as ready and the furnace at once recharged, then the melting speed is so great that, on red brass or bronze certainly, and on "half yellow and half red" almost as certainly, the gas absorption and the zinc loss per unit weight of metal will be little if any greater than in the old-style pit coke furnace. This conclusion the figures reported abundantly prove.

Its advantages are as follows: No crucible cost; low repair cost for lining, if properly and constantly patched; low labor cost for melting; little strain on the furnace tender; speed; flexibility as to size of charge without much change in fuel efficiency; and a fuel efficiency superior to oil or gas crucible furnaces.

There are, of course, some classes of work requiring such exceedingly hot metal that neither this type, not any type but pit crucible furnaces, however fired, will serve. The open-flame furnace, in the larger sizes, is not so well fitted for a jobbing foundry requiring small heats of alloys differing widely in composition, and it will not prove nearly so economical for intermittent heats as for steady running.

For large plants, using a great volume of the same alloy continually, and in which speed of production is the main object, the open-flame furnace is excellent. There are in use several types, some homemade ones as well as those made by various furnace makers. Although there are minor points of superiority or inferiority in design, the behavior of different forms of the general type is about the same.

The quality of the alloys containing less than 20 per cent of zinc from properly run furnaces of this type is satisfactory. The reputation of the goods, including those that have to stand high pressure, such as valves, made by firms using this type of furnace is sufficient proof, even without the explicit statements made in so many replies. The number of firms using this type is far below the number using the other chief types, but it is the large firm that uses this type, not the small one, and most firms that use it use a number of them, so that the tonnage melted by the open-flame furnace is great.

This type, incompetently handled, gives unsatisfactory results; properly handled, it is satisfactory from nearly every point of view, when alloys low in zinc are melted.

The maker of one form of the type has recently tried increasing the number of burners, with encouraging results. This construction will probably increase the flexibility of the furnace by insuring an adequate melting speed with a flame that is always reducing. It seems possible that, although the burners used almost invariably require a comparatively high pressure on the oil and a low pressure on the air, a burner with even higher oil pressure and lower air pressure, properly designed to give a flame of suitable length and shape to fill the melting chamber of the form of furnace used, may give better results.

It is also worthy of note that by using small charges, or, perhaps, smaller open-flame furnaces, plants in which many small heats are desired, and in which a slight contamination of one alloy by traces of the one previously melted will not do harm, could use open-flame furnaces with the maximum melting speed for any existing form of furnace, and with a better fuel efficiency than in other types of oil or gas furnaces. One maker of this type says, "Small heats in quick time produce most satisfactory metal and cost."

Owing to the lower melting speed, it appears, from the data received, that natural gas is less satisfactory in this type than oil, and that city gas or the leaner gases, like producer gas, will be still less suitable. With fuel oil at a high price, the rest of the different factors might, however, be so disturbed that, even with a lower melting speed and a greater metal loss, natural-gas firing of open-flame furnaces might be cheaper in the long run than oil firing.

OPEN-FLAME FURNACES FOR ALLOYS HIGH IN ZINC.

It will be noted that the discussion of the open-flame furnaces has so far been limited to its use for melting bronze, red brass, or half yellow and half red (say, 20 per cent of zinc) brass. Whether the open-flame furnace is in general a suitable type for melting yellow brass or manganese bronze is doubtful. There can be little doubt that alloys with a zinc content up to 18 per cent can be handled very well in it. Figure 2 shows that up to this point there is some range between the pouring temperature and the boiling point. With a zinc content of 30 to 40 per cent, however, the range is small, and hence the vapor pressure of the zinc and the tendency for the alloy to lose zinc are great. Subdivision 33 of the large table shows 10 users of open-flame oil furnaces for melting yellow brass and manganese bronze; some of the users employ this type mainly for refining scrap. One (Reply 94), though giving figures on yellow brass, states that the firm represented uses it mainly for red brass, and reports high zinc loss. The only user unqualifiedly approving this type for ordinary yellow brass is represented by Reply 173. This user pours heavy ingot at a low temperature and therefore has more leeway.

It may be possible that by taking great care to pour the metal the moment it is ready that open-flame furnaces, even on yellow brass or manganese bronze, may be operated so that the short time allowed for volatilization on account of the melting speed may overbalance the tendency for the zinc to be carried away from the large surface exposed to the waste gases.

The bulk of the evidence tends to show that careful regulation is required in order to keep zinc losses down. The burden of proof is on the advocates of the open-flame oil furnace for alloys high in zinc. Yet it would not be surprising if the over-all cost of melting even these alloys in this way should be lower than in other forms of furnaces under not uncommon foundry conditions. Small differences in plant conditions may turn the balance either way, so that it is not surprising that most replies are unfavorable to its use, that the firm whose experience is reported in Reply 192 took a long time before coming to an adverse decision, and that the rolling mill furnishing Reply 173, which pours cold, states that the furnace is applicable to the conditions in its plant.

Subdivision 35 of the large table shows that no firm using an open-flame, natural-gas furnace for alloys high in zinc has supplied data on the performance of the furnace, and as all considerations lead toward the expectation that natural gas or any otner commercial gas will not be as satisfactory a fuel as oil for such alloys, such use need not be further considered.

The open-flame furnace has a considerable use in running down borings and light scrap, even of high-zinc alloys, but as an even more common furnace for this use is the oil-fired reverberatory, such use may be considered under discussion of that type of furnace.

REVERBERATORY FURNACES.

The reverberatory furnace is essentially adapted for large-scale melting, being usually designed for handling upward of a ton of metal. In brass-foundry practice it finds its main use either for making large castings requiring more metal than would be supplied by ordinary furnaces or for refining borings and light scrap into ingots that are analyzed and remelted with the addition of such metals as are needed to bring the alloy to the required composition, one analysis serving for the whole large charge.

Several reverberatories are known to be in use, usually somewhat intermittently, for refining purposes. Little information on the operation of these furnaces for refining is at hand. The ease with which bulky borings or scrap may be charged and the ease with which the slag from the foreign materials in dirty scrap may be skimmed off in the reverberatory, combined with the greater fuel efficiency of a large furnace, make the reverberatory suitable for melting such material.

For melting metal to be cast directly without remelting, the reverberatory finds its main application in Government navy yards or in private plants making very large castings similar to those made in the navy yards. As the large castings are seldom made every day, the furnaces are as a rule used infrequently.

OIL-FIRED REVERBERATORIES.

Reply 79 covers an oil-fired reverberatory used mainly for refining. A rather high metal loss is shown, but losses in refining are naturally higher than in melting ingot or heavy scrap, on account of the greater surface of the borings which makes oxidation likely before the metal melts, if the flame is at all oxidizing.

All the replies on the oil-fired reverberatories, except Reply 80, show the high fuel efficiency that is to be expected from a large furnace. In the foundry represented by Reply 80 the furnace is run only intermittently, and difficulty from oxidation is reported. Better results might be expected if the furnace were run constantly

so that the furnace tender had continual practice in its operation. Reply 81 states that the reverberatory is used both for refining and for making large castings. Reply 82 states a preference for small types of furnaces for ordinary work, but states that with care as good results may be obtained from the reverberatory as from other types. Reply 83 states that this type is used for large manganese-bronze castings.

SOFT-COAL REVERBERATORIES.

Only three replies covering soft-coal reverberatories were received. Reply 180 covers a reverberatory used somewhat intermittently and mainly for large manganese-bronze castings. Reply 202 is the only one dealing with the constant use of this type for red brass in ordinary sand-casting practice. The furnace charge is about 1 ton. The quality of the metal is said to be satisfactory for the purposes desired, although it is stated that for high-grade bearing metal other types of furnace might be preferable. The figure for fuel consumption is higher than that reported by the other users of this type or than that specified in the literature. The three users of coal-fired reverberatories show a great variation in fuel consumption, the cause for which is not clear.

Reply 173 is from the only rolling mill in this country known to be using a soft-coal reverberatory furnace for melting yellow brass, although there are said to be several such furnaces in use for that purpose in England and Wales. This mill has such a class of work as allows cold pouring; hence the volatilization of zinc due to the flame and waste gases coming into contact with the metal may be kept low, and the fall in temperature due to ladle pouring is not a serious drawback. This firm prefers the tilting, open-flame, oil furnace to a tapping reverberatory, if fuel oil is available at a reasonable price.

For large-scale work the choice between the two types mentioned will depend on the relative price of oil and soft coal, together with the actual facts in the disputed question of the effect on the metal melted of SO_2 in the waste gases from fuels high in sulphur.

It has been suggested [a] that brass be made by melting the copper in a large reverberatory furnace (a capacity of 20 to 250 tons being mentioned), the metal being heated hot enough to allow tapping into a 2-ton or 3-ton ladle,[b] the zinc (and tin or lead in the case of red brass) being added in the ladle and the alloy then poured. This method is merely an adaptation to large-scale melting of common

[a] Anon., Reverberatory furnaces for brass melting: Foundry, vol. 41, 1913, p. 92; Brass World, vol. 8, 1912, p. 388.

[b] This heating to a high temperature could be done without notable metal loss, owing to the nonvolatility of copper.

practice (for example, see note on Reply 164), and should prove practical if the zinc may all be added as such. However, it would hardly be applicable to most yellow-brass melting in which a comparatively large quantity of gates or scrap must be melted, because if the desired quantity of this alloyed material were put into the large furnace with what new copper is to be used, conditions would be as favorable for zinc losses as under the present practice.

Ellis[a] states that an open-hearth furnace that utilized the waste heat for preheating the air supply would be most useful for melting bronze.

LARGE FURNACES FOR ROLLING MILLS.

The yellow-brass rolling mills, as a whole, have kept to square, natural-draft, pit, coal furnaces, with a charge of about 200 pounds. In an industry in which the plants average so large and turn out such huge tonnages, it is exceedingly strange that such a slow, small-scale method of melting with an expensive fuel has been retained. There are two explanations, either of which may be correct—first, that the pit, coal furnace gives a quality so much higher and a melting loss so much lower that it is, in over-all cost and efficiency, the best; second, that the great conservatism of the industry has prevented the experimental work necessary to justify the exchange of a method of melting known to produce satisfactory results for any other that has not yet proved its value in actual practice.

Some progressive mills take a great interest in the possibility of obtaining lower melting costs and have a high grade of engineering and metallurgical talent at work on the problem. Still, taking the industry as a whole, the amount of experimental work being done on furnaces is small. That some progress has been made is shown by a marked trend of opinion toward round furnaces and away from square ones, by the use of coke in some mills instead of coal, and by the use of larger crucibles in pit fires by one mill (Reply 189), of a forced-draft, tilting, coke furnace in another (Reply 79), of an open-flame oil furnace in another (Reply 192), and of open-flame, oil, and oil and coal reverberatories in still another (Reply 173).

Although several rolling mills have tried crucible oil furnaces and discarded them, one firm is using tilting oil-fired furnaces, each having a capacity of 600 pounds, and is pouring the metal directly into the molds, which are brought to the furnaces, no ladles being used. This firm may be said to have passed the experimental stage in its work on this type of furnace, as a battery of about a dozen furnaces is running 24 hours a day.

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[a] Ellis, A. B. (in discussion): Met. Chem. Eng., vol. 11, 1913, p. 413.

The practical use of this form of furnace is made possible by providing covers for the crucibles. The covers differ from ordinary flat crucible covers by having the form of a hollow cylinder with one end closed, and are put over the crucibles just as a cover is put on a tin can.

The gross melting loss on yellow-brass scrap is given as 1.8 per cent, this figure being based on several days' run on nearly 20 tons of metal. The average gross melting loss of the same firm on yellow brass when the ordinary pit coal furnaces were used without covers for the crucibles is given as 3 per cent.

The quality of the metal from these oil-fired furnaces is said to be exactly as good as that from the coal-fired furnaces. No data on oil consumption are available.

Owing to the uncertainty in regard to the price and the regular delivery of fuel oil, this firm is not, however, planning to replace its coal-fired furnaces by furnaces using oil, although under present conditions it finds the use of oil an advantage. Another reason given by this firm for not replacing coal by oil is that it expects the early perfection of electric furnaces, the advantages of which are expected to outweigh those of the oil-fired furnaces.

One other mill (Reply 95) has tried a large reverberatory (probably fired with producer gas) without commercial success, and another (Reply 36) has tried pit, oil furnaces, also without commercial success. Further work on pit or tilting oil furnaces with burners using low-pressure air and on forced-draft tilting coke furnaces would, however, probably show many plants in which the use of one or the other of these types would be distinctly advantageous. The chances are also good for finding many plants whose conditions would justify reverberatories, either coal or oil fired, or open-flame oil furnaces, whereas only few plants are now using them.

The opportunity for further experimental work is great, especally when the somewhat similar industry of copper refining, in which huge reverberatory furnaces, coal or oil fired, are the invariable rule, is contrasted with the brass-rolling industry, with its slow heats of 200-pound charges. If any method of large-scale melting that will give a higher fuel efficiency, with a satisfactory quality of metal and a low melting loss, is practicable, then the rolling mills show a great preventable waste of our supply of anthracite. From another point of view, if methods of melting are available, even at a higher cost for the heat units required, that will reduce the losses of zinc, small in percentage, but huge in the aggregate, then the rolling mills show a preventable waste of zinc that can not be viewed with complacence.

What, then, are the reasons ascribed for the use of pit coal furnaces? They may be summarized as follows:

a. The furnaces take little attention during the heat; that is, there is little or no recoaling.

b. Large-scale melting produces segregation of the melt.

c. Large-scale melting involves ladle pouring and requires too high a temperature in the furnace, conditions that cause a high zinc loss, or else involve pouring direct from furnace to mold, a procedure that is mechanically impractical with a large furnace.

d. Other types of furnaces do not give a quality of metal suitable for rolling.

e. These furnaces give a lower zinc loss than other types, owing to the velocity of the waste gases being comparatively slow.

Reason *a* is a minor one, as it is granted that the labor cost per unit weight of metal melted would be less in larger and speedier furnaces.

Segregation of copper to the bottom of the melt, giving the first ingot poured too high and the last too low a zinc content, is a function of the depth of the molten metal, and if metal from a large furnace with a hearth carrying molten metal to the same depth as that in the crucible be used, the metal being tapped first from the center and later from spouts progressively lower down into ladles the same depth as the crucibles now used, there can be no greater segregation than at present.

Pouring from a ladle is considered undesirable in rolling-mill practice for two reasons: First, there is danger of greater oxidation from the double pouring into and out of the ladle; and second, the molten metal may be chilled too much by the double pouring through the air, and by the ladle itself. Inasmuch as it is common practice, when very large ingots have occasionally to be poured, to melt the metal in the ordinary small crucibles, pouring into a larger one and from this into the large mold, the difficulty from oxidation is probably not a vital one.

The drop in temperature is a more serious matter. However, Replies 79, 173, and 192 show that ladle pouring is possible on metal that does not have to be poured too hot, as such pouring is being done by the firms represented. Replies 141, 203, S, and T, as well as the opinions of several other rolling-mill men, expressed in conversation, indicate that ladle pouring would not be impractical for the greater part of the work of the average mill. It is generally thought, however, that ingots of a weight less than 150 pounds could not be poured from a ladle.

Ladles are, of course, heated before the metal is poured into them, the heating being sometimes done in a pit fire, occasionally by the waste heat from the furnaces, sometimes by an oil or gas flame—usually pointing downward, and burning inside the empty ladle—or, in one foundry at least, in a large oil-fired furnace of the reverberatory type.

The ladles are seldom heated as hot as the metal, and, whether use is made of an ordinary crucible as a ladle or of an iron ladle

with a refractory lining, they lose heat rather rapidly. It would seem probable that there might be devised a ladle light enough to be fully portable, which would be heated, not only before it receives the metal, but also during pouring. A portable furnace has to be rather small, or else the tilting mechanism has to be very sensitive, in order to allow easy regulation of the stream in pouring. To get a high fuel efficiency, the walls have to be so thick, in order to obtain proper insulation, that the furnace may easily become too heavy to be readily portable, even by crane. Moreover, the furnace is not working at its proper task, that of melting, while being carried to and from the mold.

A heated ladle, not so heavily insulated as a melting furnace, might, however, be made that would be readily portable, and would still supply enough heat during the time of carrying to the mold and of pouring either to compensate fully for the loss of heat by radiation that would otherwise take place, or to decrease very considerably the rate of cooling.

The most desirable method would perhaps be to use one or more heated ladles, or fore hearths, light enough to allow delicate regulation of the tilting mechanism, into which some large-capacity furnace could be tilted or tapped. The molds would then be carried to the ladles mechanically, as on an endless chain, stopping just long enough at the ladle for the metal to be poured into them. Just how far the pouring might be made automatic and mechanical is a question, but more difficult mechanical problems have been solved. Copper ingots, anodes, and wire bars are poured from reverberatory furnaces by methods somewhat closely approximating the one outlined for handling brass.

In some iron foundries, particularly those making radiators, mechanical transportation of the molds is highly perfected. One large iron foundry, with a variety of output, carries the molds to the furnaces on a long endless train or moving platform running on an elliptical track. The metal is tapped into ladles from the cupolas and is then carried over the moving platform on an overhead trolley which has the form of a loop, so that the empty ladles come back to the cupola for refilling.

A somewhat similar plan, but one in which the molds are brought to the furnaces by overhead trolley will be used in a new foundry now under construction by a firm making brass and bronze castings in sand.

Carrying the furnaces bodily to the mold by crane has been often suggested, and is said to be done in one French brass foundry. Such a method, or that of putting the furnaces on wheels and bringing

them to the molds on a track, though tried to a small extent in this country, has not met with favor.

Carr,[a] however, has recently advocated the use of small open-hearth furnaces, of such design that they may be carried to the mold, for use in steel foundries.

There is no reason for believing that simply because metal is usually carried to the mold in a crucible or ladle conditions in many foundries may not warrant the molds being brought to the furnace, or the furnace to the molds.

If it be true that no known large-capacity furnace can produce metal of a quality suitable for being rolled, that in itself settles the question, but all that can be said on this is that some mills have found more difficulty in rolling metal melted in the large furnaces they have tried than in their regular ones. The problem is again largely one of operation and plant conditions. At any rate, this point is not well enough established to block the way of further experiment even on existing forms of large furnaces.

The claim that less zinc is lost by melting in small quantities in pit fires than in larger quantities in other types is more or less valid, for ordinary practice, although the difference is shown by the data collected (see fig. 21) to be less than is ordinarily supposed.

If the figures on the larger crucibles represented in Reply 189 be omitted, and if Reply 200 be omitted, because it includes figures for German silver, the averages of the data given in subdivision 10 of the large table will fairly represent the common rolling-mill conditions on brass consisting of 65 parts of copper and 35 parts of zinc.

These averages should be compared with the figures of Reply 173, given in subdivision 32 of the table. These figures represent a rolling mill using a large open-flame furnace.

The gross melting loss of 2 per cent given by Reply 173 for the oil furnace is not strictly comparable with the average of the coal furnaces, for, although the alloy consisting of 60 parts of copper and 40 parts of zinc is more volatile than that consisting of 65 parts of copper and 35 parts of zinc, yet the pouring temperature is lower. From the replies in subdivision 10 of the table that give both the gross and net losses, the average gross loss on alloys consisting of 13 to 18 per cent of zinc is found as 3.95 per cent, and the average net loss as 2.47 per cent, or three-eighths of the gross loss is recovered from the skimmings, leaving the net loss equal to five-eighths of the gross. Reply 81 states that one-third of the gross loss is recovered on yellow brass.

[a] Carr, W. M., Some observations on miniature or detachable open-hearth furnaces: Paper presented at October, 1913, meeting of the Am. Foundrymen's Assn. (not yet published).

The gross losses on yellow brass, if two replies in which data are given only on refining borings be omitted, are as follows:

Reply No.—	Per cent
81	6
83	4.7
94	4.7
189	2
192	3.4
196	4.5
Average gross loss	4.2

Five-eighths of this average gross loss, slightly less than 2.7 per cent, may be taken as the average net loss in melting yellow brass (not in running down borings) in all sizes of open-flame furnaces. This average is not far greater than the figures for alloys containing 13 to 18 per cent of zinc although a rather greater difference is to be expected. Yet, as the melting losses as figured above are based chiefly on furnaces with charges smaller than 2,500 pounds, in which the melting speed is lower and the molten-metal surface per hundredweight is greater, the average figures of 4.2 per cent gross and 2.7 per cent net melting losses may be assumed as fully large enough to cover rolling-mill practice on high-zinc alloys, especially as the two figures that really are on rolling-mill practice show, respectively, 2 and 3.4 per cent gross loss.

As no oil-consumption figure was given in reply 173 for the 2,500-pound furnace, it may be taken from the curve in figure 20 as 1.4 gallons per hundredweight, as this curve is drawn for alloys both high and low in zinc, and as a high-zinc alloy should take even less than the average for alloys with both high and low zinc content.

The comparison between representative large-scale and small-scale furnaces for yellow brass then becomes as follows:

Results of melting brass in large-scale and in small-scale furnaces.

Source of data.	Kind of furnace.	Weight of charge.	Time per heat.	Time per hundred-weight.	Fuel per hundred-weight.	Gross melting loss.	Net melting loss.
		Pounds.	*Hours.*	*Hours.*	*Gallons.*	*Per cent.*	*Per cent.*
Reply 173	Open-flame oil	2,500	1.8	0.072	[a] 1.4	[a] 4.2	[a] 2.7
					Pounds.		
Average of replies in subdivision 10 of large table	Small pit coal	200	1.9	0.950	33	3.1	1.92

[a] Assumed.

It would take about 13 of the small furnaces to produce metal as fast as the one large furnace would produce it. Subdivision 10 of the large table shows that the average life of the lining of the small furnaces is 800 heats, whereas the figure given for the open-flame furnace,

750 heats, is rather lower than the average. It may therefore be roughly assumed that the cost for furnace repairs in each type will not be notably different. The labor charge will, in general, be considerably less with the larger furnaces, but as exact figures are not available for mill conditions that are comparable for both types, figures for this charge must be omitted.

The average life of the crucibles in the small furnaces represented in subdivision 10 of the large table is 34 heats. At the ordinary price for a No. 70 crucible, this life means a crucible expense of about 2.5 cents per hundredweight. The prices of fuel will vary with the locality, but for comparison it may be assumed that the locality is such that $6 per ton for anthracite coal and 6 cents per gallon for oil are the ruling prices, giving 8.25 cents for coal and 8.4 cents for oil per hundredweight of metal melted.

The zinc loss in the coal furnace, with zinc at 5.6 cents per pound, is 10.75 cents, whereas in the open-flame furnace it is 15.12 cents.

The costs per hundredweight, exclusive of labor charges, would be as follows:

Cost of melting brass in representative large and small furnaces at assumed prices of fuel.

Kind of furnace.	Cost of fuel.	Value of zinc loss.	Crucible cost.
	Cents.	*Cents.*	*Cents.*
Coal	9.90	10.75	2.50
Oil	8.40	15.12	....
Gain or loss in coal furnace	−1.50	+4.37	−2.50

Total saving per hundredweight of metal in coal furnace, 0.37 cent.

The advantage of 37 cents per hundredweight, exclusive of labor charges, for the present type of furnaces should be slightly increased on account of a small charge for power to run the blower and oil pump for the oil furnace and for interest charges on the greater cost of the oil furnace and equipment, and should be slightly decreased by the greater rental charge for the greater floor space occupied by enough coal furnaces to give the same output as with the oil furnace.

Were similar figures given on red brass in ordinary sand-casting practice it would probably be found that at the fuel prices given and with similar metal losses in both types of furnace, the advantage would be on the side of the large open-flame oil furnace, because the foundries in general do not get quite as low a coal consumption per hundredweight as do the rolling mills and the labor cost for melting is less (metal melted per furnace tender per hour being greater) in the larger furnace. This relation is substantiated by the tabulated data, which indicate that on alloys low in zinc the average quantity of

metal melted per hour per furnace tender in the common sizes of pit-coal or coke furnaces, with natural or forced draft, is between 350 and 450 pounds per hour; in the pit, oil furnaces 450 to 550 pounds; in forced-draft, tilting, coke furnaces, about 700 pounds; in tilting-crucible, oil furnaces 500 to 700 pounds; and in open-flame, oil furnaces or reverberatories about 1,000 pounds.

The cost figures given are not to be taken as exact or actual ones and are cited only in order to give a more concrete idea of the relative amounts of the main expenses of melting and how each of these will vary with change in conditions.

If the cost of oil remained at 6 cents per gallon, the price assumed above, and coal rose to $7.50 per ton, the advantage would amount to 2.1 cents per hundredweight in favor of oil. If oil then rose to 8 cents per gallon, coal remaining at $7.50 per ton, the advantage would become 0.7 cents per hundredweight in favor of coal.

If the zinc loss in the oil furnaces were reduced from 2.7 to 2.2 per cent, that in the coal furnace remaining the same, the advantage, at the three ratios of fuel cost noted above, would be on the side of the oil furnace by 2.43, 4.9, and 3.5 cents, respectively.

Thus it takes little change in any of the factors to alter the balance in favor of one type or the other. As stated at the beginning, there is no "best" furnace, as the choice depends on the combination of so many variables that are affected by the locality of the plant and by its own shop conditions.

However, the loss of metal in melting is almost invariably the highest of the four main items of melting cost, which usually rank in the following order: Loss of metal in melting, labor charges, fuel, and crucible cost.

Hence if a furnace can be found that, while producing the right quality of metal, will decrease the metal loss notably and lower the labor charges and crucible cost somewhat, even though it involves a higher fuel cost, it will be an economical one.

But the discussion of the curves for the boiling-points of copper-zinc alloys and the effect of the volume of the products of combustion on the volatilization of zinc has shown that there is little hope of developing any type of fuel-fired furnace that will give sufficiently lower metal losses than do existing types when properly run to pay for other disadvantages. The only method of developing heat in a furnace that will not involve the continuous passage of waste gases over the metal, continually sweeping out the zinc, is that of electric heating. It is therefore necessary to consider the perfection of electric furnaces for brass melting as the probable main line of improvement in melting equipment.

POSSIBLE IMPROVEMENTS IN FURNACES AND ACCESSORIES.

DEVELOPMENT OF THE ELECTRIC FURNACE.

METAL LOSSES IN THE ELECTRIC FURNACE.

With electric heating it is easy to design a furnace that will either be perfectly gas tight, or so nearly so that the passage of air or gases over the metal will be exceedingly slow. That is, the furnace can be closed tightly enough so that not much more zinc vapor will be lost than that theoretically corresponding to the partial pressure of the zinc vapor from the particular alloy used at the highest temperature within the furnace.

The maintenance of a neutral or reducing atmosphere in the melting chamber will also be fairly easy. Hence volatilization, oxidation, and gas absorption can undoubtedly be brought much lower than in any other type of brass furnace. Sulphur, of course, would be wholly eliminated. Moreover, as far as getting a low melting loss and a good quality of metal is concerned, the electric furnace should be more "fool proof" than any existing type. Although, with fuel furnaces, the leaving of metal in the furnace too long ("soaking" it) involves high melting loss and gas absorption, soaking in the electric furnace, though undesirable as regards production and power consumption, should have little or no bad effect on the quality of the metal.

The speed of melting in an electric furnace is great. With furnaces of the size of the open-flame or reverberatory furnaces now in use the speed can, if desired, be made considerably greater than in those types that, for speed, stand at the head of present types. In small crucible furnaces, say with a capacity up to 300 pounds, the speed, and hence the output, can easily be made three or four times that of the present average.

If furnaces of the same size be compared, the labor cost of melting in electric furnaces should be lower than that in any present type, because of their easy regulation and also because the heat radiated from their exterior is far less. It will doubtless be easier to teach a furnace tender to handle an electric furnace so as to produce good metal than to teach him how to operate an oil or gas furnace.

There are two main problems that hinder the rapid development of the electric brass furnace, that of obtaining a low enough power cost per hundredweight of metal melted to make the other savings overbalance that item, and that of designing an electric furnace that will have a low upkeep cost. The power cost is a function of two factors, the efficiency of the furnace and the price for which electric power may be obtained.

The efficiency of a properly designed electric furnace is far and away greater than that of any other furnace. Although the efficiency of fuel-fired furnaces for melting brass, as has been seen, runs between $1\frac{1}{2}$ and 16 per cent, with an average of perhaps 7 per cent, an electric furnace should give 40 to 75 per cent of the theoretical efficiency, depending on the size of the furnace and on how constantly it is used.

The cost of electric power is a more serious factor, but, taking a long look ahead, the indications are that although all fuels seem bound to rise in price, the cost of electricity, produced from those fuels, with a growing development of competing electricity produced from water power, is not likely to increase at the same rate. A steady load, such as that for brass melting would be, is a desirable one for a central-station power plant, and central-station owners are taking a keen interest in the development of electric brass furnaces.

At first, in localities favored with cheap power, the electric furnace will find use for general melting, and in other localities will satisfy special conditions, such as melting yellow brass and refining both yellow and red brass borings, in which the metal losses are highest at present, and melting metal for a product for which exceptionally hot metal is required, as the efficiency of fuel-fired furnaces falls off rapidly as the temperature to which the metal must be raised increases, whereas the efficiency of the electric furnace does not fall so rapidly. Whether the quality of electrically melted red brass and bronze will be enough better than that from fuel furnaces to justify the use of the electric furnaces, under conditions of high power cost, on alloys that can be melted with little loss in existing furnaces is a question that can be answered only by commercial experience. There are plainly enough plants where, even at existing power costs, a good electric furnace should be able so to compete with any present type on over-all cost as to justify the development work necessary to bring it to a sufficient state of advancement for commercial use.

The matter of upkeep cost, such as for electrodes and linings, is not to be greatly feared, although it is not simple.

Both the brass rolling mill and the brass-foundry operators are watching the development of electric furnaces with keen interest. There was scarcely a man interviewed on visits made in collecting the data presented in this bulletin who did not express himself as convinced that the electric furnace is the ultimate type. In fact, the mentors of the brass industry are so inclined to think that the electric furnace possesses every advantage desirable in a brass furnace that progress on the problem will be best served if designers and makers of electric furnaces for melting brass will be conservative in their claims and will not put the furnaces on the market until they have

been thoroughly tested. The attitude of furnace users toward the introduction of electric heating is so favorable that it would be better to accept the delay necessary for the commercial perfection of the electric furnace for melting brass than to run the risk of giving the furnace a bad name by putting on the market an inefficient or mechanically weak furnace.

The interest of the foundry industry in electric melting is shown by the comments of Moldenke,[a] Krom,[b] Langdon,[c] Sperry,[d] Bragg,[e] and Dean.[f]

That electric-furnace men have given attention to the problem both as regards theory, and to some extent on an experimental basis is shown by the articles of Richards,[g] Fitzgerald,[h] Weeks,[i] Hansen,[j] Clamer,[k] Hering,[l] Bensel,[m] Sperry,[n] Scott,[o] and Johnson and Sieger.[p]

Of the many possible types of electric furnaces that might be applied to brass melting, some that deserve closest attention because of their manifest applicability to the problem are the indirect-arc furnace, the "pinch-effect" furnace, heated by the resistance of the metal itself, and the resistance furnace of reverberatory or tilting form, with indirect heating from a resistor, all of which involve ladle pouring. To meet the needs of melters requiring metal too hot to allow ladle pouring, the crucible furnace of the lift-out type, with indirect heating from a resistor, should be included.

The Bureau of Mines is conducting experiments on the design and operation of electric furnaces for brass melting, the results of which will be published as soon as warranted by the progress of the work. Consequently, further comment on electric furnaces is not fitting at present.

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[a] Moldenke, Richard, Electric furnaces for the foundry: Electrochem. Met. Ind., vol. 5, 1907, p. 160.

[b] Krom, L. J., Development of melting furnaces: Metal Ind., vol. 7, 1909, p. 287.

[c] Langdon, P. H., Economics of the future: Metal Ind., vol. 10, 1912, p. 467.

[d] Sperry, E. S., Editorials: Brass World, vol. 8, 1912, pp. 305, 386.

[e] Bragg, C. T., Modern brass-foundry progress: Trans. Am. Brass Founders' Assn., vol. 4, 1910, p. 43.

[f] Dean, W. R., Discussion: Trans. Am. Inst. Metals, vol. 6, 1912, p. 76.

[g] Richards, J. W., Electric furnaces in nonferrous metallurgy: Met. Chem. Eng., vol. 8, 1910, p. 233.

[h] Fitzgerald, F. A. J., A new electric resistance furnace: Trans. Am. Electrochem. Soc., vol. 19, 1911, p. 261; Met. Chem. Eng., vol. 9, 1911, p. 283.

[i] Weeks, C. A., Melting nonferrous metal in an electric furnace: Met. Chem. Eng., vol. 9, 1911, p. 363.

[j] Hansen, C. A., Electric melting of copper and brass: Trans. Am. Inst. Metals, 1912 (not yet published).

[k] Clamer, G. H., and Hering, C., The electric furnace for brass melting: Trans. Am. Inst. Metals, vol. 6, 1912, p. 95; Brass World, vol. 8, 1912, p. 357; Foundry, vol. 40, 1912, p. 483; Clamer, G. H., Electric melting of copper and brass: Trans. Am. Inst. Metals, vol. 6, 1912, p. 129.

[l] Hering, C., Advantages of small high-speed electric furnaces: Met. Chem. Eng., vol. 11, 1913, p. 183.

[m] Bensel, F., Versuche zur Verminderung der Metall verluste beim Messingschmelzen: Metallurgie, vol. 9, 1912, p. 533; abstracted in Chem. Abs., vol. 6, 1912, p. 3256; Jour. Soc. Chem. Ind., vol. 31, 1912, p. 879; Jour. Inst. Metals (British), vol. 8, 1912, p. 353: Jour. Franklin Inst., vol. 175, 1913, p. 150.

[n] Sperry, E. S., An experimental electric-furnace plant: Brass World, vol. 9, 1913, p. 356.

[o] Scott, E. K., Electric furnaces in iron and brass foundries: Foundry, vol. 4, 1913, p. 380.

[p] Johnson, W. McA., and Sieger, G. N., Electric furnaces, their design, characteristics, and commercial application: Met. Chem. Eng., vol. 11, 1913, p. 506.

USE OF POWDERED COAL.

Another possibility in the development of brass furnaces is the use of finely pulverized bituminous coal for heating the furnaces. The rise in the price of fuel oil has caused the suggestion from many quarters that powdered coal could be applied to purposes for which fuel oil is now used. No brass foundry has yet made a thorough test of powdered coal, though one firm, now using mainly open-flame oil furnaces, has planned experiments. No tests on which they are ready to report have yet been made.

One furnace maker writes as follows:

> We hope at an early date to be able to convince some of the large users of brass furnaces that powdered coal is the ideal fuel for the purpose, but it could only be used by the larger manufacturers, as it would not pay to put in a coal milling and distributing plant for the small amount of fuel used in the ordinary brass foundry.

Pulverized coal has practically replaced fuel oil in rotary cement kilns, and Peters [a] reports that at one copper smelter the use of coal, powdered so that 90 per cent passed a 150-mesh sieve, saved 15 to 20 per cent of the fuel used in the direct firing of the coal in a reverberatory and was considered a success, although the system was not permanently used. Another smelter tried it, but the flues were clogged with the ash and it was abandoned in favor of the use of fuel oil, as the smelter was in a locality where oil was cheap. Rawlins [b] states, however, that at one copper smelter a powdered-coal fired reverberatory has been in successful use for two years. In cement work an oxidizing flame is used, whereas for melting brass a reducing flame is necessary.

The regulation of the nature of the flame from powdered coal, blown into the furnace through a nozzle or burner by a jet of air, is considered by cement men to be as easy as is the regulation of the flame of gas. However, most burning of powdered coal is under such conditions that complete combustion to CO_2, even though it involves excess air, and hence an oxidizing flame, is attempted.[c]

Barnhurst [d] states that on account of the high temperatures of the flame when there is no excess of air an excess of 50 to 100 per cent is commonly used.

Raymond [e] states that to get complete combustion of the coal, at least four times the calculated volume of air must be used. Meade [f] states, however, that pulverized coal may be burned with almost exactly the theoretical volume of air, and that if a reducing flame be

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[a] Peters, E. D., Practice of copper smelting, 1911, p. 355.

[b] Rawlins, J. W., In discussion on paper by J. Lord, "Pulverized Coal in Metallurgical Furnaces," Proc. Eng. Soc. Western Pennsylvania, vol. 29, 1913, p. 363.

[c] See Damour, E., Industrial furnaces: 1906, p. 272 (translated by A. L. J. Queneau.)

[d] Barnhurst, H. R., Pulverized coal as fuel: Met. Chem. Eng., vol. 11, 1913, p. 127.

[e] Raymond, A. W., Pulverized coal as fuel: Met. Chem. Eng., vol. 11, 1913, p. 108.

[f] Meade, R. K., Use of pulverized coal for foundry purposes: Trans. Am. Foundrymen's Assn., 1910, p. 40.

desired it may be easily produced. He states [a] that the volume of the air in the jet that carries the coal into the furnace is only 20 per cent of that required for combustion, a statement that would indicate that a reducing flame might be readily maintained.

Wood [b] describes a duplex burner, similar to the concentric burner used for oil, which, he states, produces "by far the most flexible and economical feed in existence." By the use of such a burner it should be possible to maintain a reducing flame.

Meade [c] states that by pulverizing the coal a lower grade may be used than is successfully used even in the gas producer. The present interest in the use of powdered coal is shown by the fact that three papers on that subject, by Meade,[d] Barnhurst,[e] and Quigley,[f] were presented at the October, 1913, meeting of the Iron and Steel Committee of the American Institute of Mining Engineers.

Powdered coal would doubtless give a good fuel efficiency, but in respect to zinc losses, because of the volume and velocity of the waste gases, would not offer much advantage over any of the more common fuels, with the exception of producer gas. Powdered coal would hardly be applicable to open-flame furnaces as now constructed, as the blast incident to its use would blow the ash out of the furnace. Whether in a reverberatory the formation of a slag on the metal, due to the ash of the powdered coal, would entrain metal that would with difficulty be recovered from the slag, or whether it would form a good cover to hinder volatilization of zinc, can be determined only by experiment.

The low cost and constant availability of bituminous coal is in favor of powdered coal, but the expense of the pulverizing plant and the difficulty of keeping the flues from becoming clogged with the ash are against it.

It would seem worth while to try the application of powdered coal to reverberatory or open-flame brass furnaces, if the open-flame furnaces were provided with exhaust flues to carry off the ash.

GAS COMBUSTION WITH THEORETICAL AIR SUPPLY.

The low thermal efficiency of furnaces fired in the ordinary ways is largely due to two causes—incomplete combustion and the loss of sensible heat in the waste gases. Less than one-third as much heat is developed in burning carbon to CO as in burning it to CO_2.

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[a] Meade, R. K., op. cit., p. 44.

[b] Wood, W. D., Powdered fuel for locomotives: Ry. Age Gaz., July 4, 1913; Eng.Mag., vol. 45, 1913, p. 881.

[c] Meade, R. K., Use of pulverized fuel for heating metallurgical furnaces: Trans. Am. Inst. Chem. Eng., vol. 1, 1908, p. 98.

[d] Meade, R. K., The use of powdered coal as fuel (not yet published).

[e] Barnhurst, H. R., The use of powdered coal as fuel for metallurgical furnaces: Bull. 82, Am. Inst. Min. Eng., October, 1913, pp. 2523–2532.

[f] Quigley, W. S., The use of powdered coal as fuel (read by E. W. Shinn) (not yet published).

There is a loss of sensible heat in waste gases for several reasons. First of all, the hot gases pass through the furnace so rapidly that they do not become cooled to the temperature of the charge that is being heated; if they did, the waste gases at the beginning of a heat would leave a brass furnace at the same temperature as that of the cold metal charged and at the end of a heat would leave the furnace at the same temperature as that of the molten metal. The nearer to the object to be heated the area is in which the heat is developed, the more of the heat goes into the object and the less up the stack. In an ordinary crucible gas furnace, for instance, much of the flame is not close to the crucible and the heat from the farther parts of the flame or of the hot gases has to be transmitted through a layer of flame or gas that has been slightly cooled by contact with the crucible. This condition means that there is a low temperature gradient throughout the furnace from the outer part of the combustion chamber (assuming the furnace walls to be hot) to the crucible. The lower the temperature gradient the less rapid the transmission of heat. Hence if the same volume of gas could be burned in a cylindrical sheet of flame about the crucible, as the heat energy would be developed over a larger area than with a single flame, the transmission of heat to the crucible would be more rapid. One form of gas burner, in order to give more flame surface, mixes the gas and air and shoots it into the furnace in three or more small flames instead of the one large flame.

When more than the theoretical volume of air is admitted with the combustible gas, two effects are produced—dilution of the waste gases with the excess air, thus wasting all the energy used in heating the excess air up to the temperature of the exit gases, and a lowering of the temperature of the flame itself through the dilution.

The temperature of a flame from a combustible gas and one and one-half times the theoretical volume of air is only about two-thirds as high as of one with exactly the theoretical amount. Hence, if the gas be burned with a deficiency of oxygen or with too little excess to get complete combustion to CO_2, not all of the possible heat is developed. If it be burned with an excess of air, the heat is all developed, but much of it is wasted through dilution of waste gases and lowering of flame temperature by the excess air. It is quite possible that what a foundryman calls a "reducing flame" in an oil or gas furnace is one in which considerable CO is present and, at the same time, some air in excess of the theoretical; that is, both CO and O_2 may be present in the waste gases. This condition is common in industrial furnaces when an attempt is made to avoid an oxidizing flame. In this quite possible case both causes of low fuel efficiency are present.

If, on the other hand, the theoretical volume of air, and that only, could be used, so that the waste gases contained neither CO nor O_2, the highest fuel efficiency attainable with any particular fuel would be reached.

It is usually considered impractical to run an ordinary gas furnace with the theoretical mixture of gas and air, because the mixture is highly explosive and "strikes back" into the burner. Garland,[a] however, claims that by the use of a special system of burner and control valves producer gas may be burned with only the theoretical amount of air.

In order to prevent this back-firing, a special form of burner is used. There are two forms of such a burner—the Méker and the surface-combustion.

The Méker burner is a laboratory device that causes complete mixing of gas and air and passes them at a high rate of speed through a grid, an arrangement that prevents back-firing after the principle of the Davy safety lamp.[b]

Small furnaces of this type have been built for laboratory use, and in one supplied with compressed air it is stated that 105 grams of platinum was melted in 17 minutes. Whether or not such a burner in which the grid will not become hot enough to allow back-firing can be made on a large scale is not known, but at any rate no furnace of commercial size using such a burner has appeared on the market for brass melting. However, a method of combustion has been developed—the so-called surface or flameless combustion—which is said to attain the end of allowing the combustion of an explosive mixture of gas and only the theoretical air supply, with prevention of back-firing, as well as the almost complete suppression of actual flame.

SURFACE COMBUSTION.

The essentials of surface combustion were described by Lucke[c] in 1901. He mentions a method of "increasing the area of the surface of combustion" that is practically identical with that widely advocated in the last couple of years by Bone and his coworkers, Wilson and McCourt, and by Schnabel. The method of getting the "surface" combustion is to inject a mixture of combustible gas and air in theoretical or nearly theoretical proportions, at a speed greater than the velocity of back firing, on a bed of incandescent, granular refractory material, or through a porous refractory diaphragm.

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[a] Garland, C. M., A system of burning producer gas: Iron Age, vol. 92, 1913, p. 664.

[b] Field, C. G., A novel development in laboratory burners and furnaces: Met. Chem. Eng., vol. 9, 1911, p. 222.

[c] Lucke, C. E., Surface combustion: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 78.

Bone[a] calls the combustion of a gas under such circumstances "flameless, incandescent, surface combustion." He emphatically denies that such combustion involves a flame, and considers that the incandescent solid material promotes the combustion within its interstices entirely without flame. Mache,[b] Kinzbrunner,[c] and Teclu,[d] as well as several engineers in this country who have experimented along this line and with whom the subject was discussed, strongly oppose this point of view, considering that the combustion is a true flame, subdivided into small flames within and at the surface of the porous or granular incandescent body. Webster's[e] definition of a flame as "a stream of burning vapor or gas emitting light and heat" would seem to include surface combustion within the category of flame.

Whether surface combustion is flameless or not is, however, merely a matter of terminology, and has no bearing on the efficiency of the process, which is the vital point.

The industrial development of surface combustion has so far been mainly along the lines of small household appliances and of boiler firing, in which it is claimed that over 90 per cent of the net heat of combustion of the gas is transmitted to the water.

Lucke[f] describes very fully its application to household appliances, as well as the principles involved.

The manufacture of porous diaphragms does not seem to have yet reached the point where a diaphragm of the proper degree of porosity combined with sufficient refractoriness to withstand the temperature needed for brass melting has been made, the diaphragm

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[a] Bone, W. A., Surface combustion: Jour. Franklin Inst., vol. 173, 1912, p. 101; Ber. Deutsch. chem. Gesell., vol. 46, 1913, p. 5; Stahl und Eisen, vol. 32, 1911, pp. 1095, 1272; Chem. Abs., vol. 6, 1912, pp. 925, 2995, 2960; vol. 7, 1913, p. 1597; Engineering (London), vol. 91, 1911, p. 487; Jour. Soc. Chem. Ind., vol. 29, 1910, pp. 744, 1138, 1148; vol. 31, 1912, p. 524; Proc. Am. Gas Inst., 1911, pt. 1, p. 565; Jour. Gas Light., vol. 118, 1912, p. 432, vol. 121, 1913, p. 242; see also: Schundt, L., Flameless combustion: Gas World, vol. 58, 1913, p. 208; Chem. Abs., vol. 7, 1913, p. 1597; Blum, R., Flameless combustion and its industrial importance: Zeitschr. Deutsch. Ing., vol. 57, 1913, p. 281; Chem. Abs., vol. 7, 1913, p. 1797; Blackwell, H. C., Surface combustion: Chem. Eng., vol. 16, 1913, p. 91; Am. Gas Light Jour., vol. 97, 1912, p. 90; Chem. Abs., vol. 6, 1912, p. 3509; Berthier, A., Catalytic combustion and its industrial uses: Lumiere Elec., vol. 19, 1912, p. 236; Chem. Abs., vol. 6, 1912, p. 3322; Benner, R. C., Surface combustion: Min. Sci. Press, vol. 104, 1912, p. 336; Chem. Abs., vol. 6, 1912, p. 2995; Ellis, C., Flameless combustion: Bull. Am. Inst. Min. Eng., No. 69, 1912, p. 3509; Chem. Abs., vol. 6, 1912, p. 3509; Am. Gas Light Jour., vol. 97, 1912, p. 257; McCourt, C. D., Bonecourt process of surface combustion: Electrician, vol. 71, 1913, p. 132; Blum, R., Die flammenlose Verbrennung und ihr Bedeutung für die Industrie: Zeitschr. ver. deutsch. Ing., vol. 57, No. 8, 1913; Metal und Erz., vol. 10, 1913, p. 337; Krull, F., Die flammenlose Oberflächen verbrennung; Zeitschr., angew. Chem., vol. 26, 1913, p. 401 (Aufsatz); Seager, J. A., Surface combustion: Steam, vol. 12, 1913, p. 70; Canaris, C., Surface-combustion furnaces: Chem. Abs., vol. 7, 1913, p. 3655; abstracted from Feuerungstechnik, vol. 1, 1913, p. 373; Bunte, H., Flameless surface combustion: Jour. gasbel., vol. 56, 1913.

[b] Mache, H., Über die sogenannte "flammerlose" Gasheizung: Zeitschr. angew. Chem., vol. 26, 1913, p. 163; Chem. Abs., vol. 7, 1913, p. 2108.

[c] Kinzbrunner, C., Surface combustion: Met. Chem. Eng., vol. 2, 1913, p. 53; Chem. Abs, vol. 7, 1913, p. 3400. Abstracted from Feuerungstechnik, Nov. 15, 1912.

[d] Teclu, N., Characterization of flame: Jour. Chem. Soc., vol. 104, pt. 2, 1913, p. 757, and Chem. Abs., vol. 8, 1914, p. 766.

[e] Webster's International Dictionary, 1911, p. 566.

[f] Lucke, C. E., Design of surface-combustion appliances: Jour. Ind. Eng. Chem., vol. 5, 1913, pp. 801, 960.

burner being so far applied mainly to household appliances, such as toasters, and to the evaporation of water solutions. If a diaphragm of sufficient refractoriness and mechanical strength could be made, the diaphragm burner could be suspended over the whole surface of the metal bath in a furnace of the reverberatory form. Pending the development of such a diaphragm, two methods of applying surface combustion to brass melting have been proposed and are outlined below.

One method is to pack the granular refractory material into a suitable refractory tube which is placed within the bath of molten metal inside the crucible or the melting chamber of the furnace. This arrangement is said to be peculiarly effective in the case of lead and type metal, the melting being continuous, as solid metal is added as fast as molten metal is drawn off. Efficiencies of nearly 70 per cent on lead and of 55 per cent on aluminum are claimed for a furnace of this design containing the granular refractory in an iron tube.[a]

When mechanically possible, internal heating of this sort would be highly efficient. Tubes of graphite, alumina, or magnesia have been suggested for high-temperature work, but there are great mechanical difficulties in designing an internally heated furnace of this sort in which the heating tube or tubes do not occupy so large a part of the melting chamber as to make the charging, of large ingots for example, hazardous through breakage of the tube. If too little tube surface were allowed, the speed of the furnace would not be great enough. On the other hand, the waste gases from such tubes could be carried off without involving any flow of gas over the metal itself, an arrangement that would be a great advantage as regards zinc losses.

The other furnace suggested for such purposes as brass melting is very similar to a tilting, forced-draft, coke furnace in which the coke below and around the crucible is replaced by the granular, refractory material through which the mixture of gas and air is forced. This bed of refractory material would, however, not be as thick as the bed of coke in the coke furnace, as the combustion is said to take place within a thin layer at the surface of the bed. Small furnaces of this sort have been built, and it is said[b] that a cold charge of cast iron (weight of charge and size of crucible not given) may be melted in 10 minutes.

In these small furnaces the gas and air, in practically theoretical proportions, enter the pipe leading to the refractory material and become mixed, and the mixture is admitted from below into the granular, refractory material at a rate greater than that of the prop-

[a] Bone, W. A., Oberflächenberbrennung: Chem. Zeitschr., vol. 36, 1912, pp. 1440, 1455.

[b] Kershaw, J. B. C., Flameless or surface combustion: Met. Chem. Eng., vol. 9, 1911, p. 629; Chem. World, vol. 1, 1912, p. 198.

agation of the explosion waves for the mixture in the pipe, so that back-firing is prevented. In larger furnaces it might be necessary to have several outlets for the mixed gas and air, in order to have approximately the same pressure throughout the mass of granular refractory material. The refractory material used must be able to withstand the combustion temperature attained with the gas in use, which is high with the richer gases, such as natural gas or city gas, because the factors of incomplete combustion and of air excess, which decrease the flame temperature in ordinary burners, are not acting with surface combustion. For the richer gases the high temperatures developed make it necessary to use such refractories as silicon carbide (carborundum or crystolon), magnesia, or alumina. Calcined fire clay, or ganister, is said to be suitable for the granular refractory material when lean gases, such as blast-furnace or producer gas, are used.

If the accounts are correct, surface combustion allows the use of only the theoretical volume of air, although complete combustion is attained, a result that means that the minimum possible volume of waste gases is formed; also it may be applied so as to give a large heating surface close to the crucible. Thus as regards fuel consumption and, to some extent, metal loss, it goes a long way toward meeting the requirements for more efficient gas heating than is effected in the present type of crucible gas furnaces. If surface combustion can do half what is claimed for it, it is worthy of serious consideration, particularly as it should be peculiarly adapted to the cheaper gases, such as blast-furnace and producer gas, as well as to city or natural gas. Lewes [a] states that fuel oil, finely atomized by the correct proportion of air, may be used in surface-combustion burners if the granular material is previously heated.

In view of the foregoing it appears probable that experimental work on the application of electric heating, of powdered coal firing, and of surface combustion of gases to brass furnaces offers considerable promise, because it is quite possible that there may be particular alloys on which, or particular conditions under which, each one of the three methods of heating might prove better than any method yet applied.

USE OF HEATED LADLE.

As the economy of large-scale melting is acknowledged, any means of enabling the use of large tilting or tapping furnaces by rolling mills, and by those foundries whose class of work is so light that pit furnaces are now essential, would be most desirable. Although there may be some work for which the extra oxidation and the increased

[a] Lewes, V. B., Cantor lectures on liquid fuel: Jour. Roy. Soc. Arts., vol. 61, 1913, pp. 698, 699, 702. See also McCourt, C. D., Combustion of liquid fuel: Jour. Soc. Chem. Ind., vol. 32, 1913, p. 1097.

fall in temperature from two pourings through the air would prevent the use of a pouring ladle, yet there are certainly many plants where the feasibility of ladle pouring would be measured by the fall of temperature of the metal while in the ladle itself. A heated ladle would enable all molds poured from it to be poured at approximately the same temperature, instead of the necessity, as at present, of pouring the first ones hotter and the last ones colder than is really desired.

As has been indicated under the discussion of reverberatory furnaces for rolling mills, it should not be unduly difficult to devise a ladle to which enough heat might be supplied during the carrying of the metal from furnace to mold and during pouring, either to compensate entirely for the loss of heat that occurs in a ladle that is heated only prior to receiving the metal, or at least to greatly decrease the rate of cooling of the metal. Such a heated ladle might be heated by gas, oil, or electricity, and might be made either fully portable or portable through a limited radius, an arrangement that would probably be sufficient for rolling-mill use. Hence the development of a heated ladle should be classed among the tasks of those who are endeavoring to improve the efficiency of brass-melting devices.

USE OF PYROMETERS FOR MOLTEN BRASS.

No matter what type of furnace be used, the greatest efficiency is obtained by taking the metal from the furnace the moment it has reached the proper temperature. Heating the metal too hot, or "soaking" it in the furnace after it has once reached the proper temperature, delays production by cutting down furnace capacity, increases the danger of oxidation and of gas absorption, increases the volatilization of zinc, and is an utter waste of fuel.

Moreover, for each particular pattern or mold, and for each different alloy to be cast therein, there is some definite temperature at which the best results are obtained, or some definite range of temperatures outside of which results are not satisfactory. If the metal be poured when too hot, a rough or dirty casting may result. If poured when too cold, misruns, "spills," or blowholes occur, or oxides and dross that would otherwise have risen to the top of the ladle in metal not too cold may be trapped in pouring and produce a porous casting.

In some alloys, as the light aluminum alloys, the greatest strength and greatest freedom from cracked castings is obtained by pouring the metal when at the coldest temperature at which it will fill the mold and be free from blowholes. In others, like yellow brass or manganese bronze, the evidence tends to show that the metal should be poured when rather hot. In still others, as gun metal, it appears probable that poorer results are obtained by pouring either above or below a given temperature range.

It is most desirable that the proper pouring temperature for the alloy and mold in use be determined, and thereafter used, and that the temperature to which the metal is heated in the furnace should be noted. To attain these ends there must be some method of measuring the temperature. Luckily, with brass and bronze, the temperature is high enough so that a fair approximation may be made by eye on the basis of the brightness of the molten metal. With yellow brass the amount of zinc fumes gives an indication of the temperature, or an approximation may be made by the viscosity of the metal when stirred.

Some men become skilled in judging temperature after long experience in melting, whereas some never acquire much ability in the matter. Even the most skilled man is often at loss to tell the proper temperature by eye on a very dark or a very bright day, or in working with an alloy that he has not been using for some time. Therefore, some instrument for measuring temperatures that will meet the requirements of everyday brass melting, both in the furnace itself and at the mold, is badly needed.

On an experimental scale, when neither time nor cost is so vital as in regular work, the problem is satisfactorily met for brass by pyrometers using either platinum or base-metal thermocouples, the platinum couples being, of course, suitably protected. For ordinary work the problem is far more difficult. It is easy enough to get a pyrometer that will indicate the temperature of a pot of brass, but to get one that will give a quick enough reading and have a long enough life to make it a foundry tool instead of a mere laboratory instrument is as difficult as it is desirable.

The problem has been rather satisfactorily solved for the comparatively low temperatures of molten aluminum, and progressive aluminum foundries are using pyrometers freely and find them valuable. There are half a dozen makes of pyrometers that are more or less strongly advocated by their makers for use in the melting of brass and bronze, but none of them has yet shown sufficient rapidity of reading combined with sufficient length of life to justify its being classed as a desirable foundry tool. Brass pyrometers are still laboratory instruments.

There are perhaps a score of plants in the country that make occasional use of a pyrometer in "checking up the melter's eye," or on very important work, but the plant is yet to be found in which the use of the pyrometer in connection with melting brass has been the success that pyrometers for use in melting aluminum have proved themselves in the aluminum foundry.

To repeat, then, the development of a practical pyrometer for molten brass and bronze is to be classed as one of the pressing needs of the industry.

USE OF AN ACCURATE OIL METER.

One reason for the variations in the oil consumption per hundredweight of metal melted reported by various users is the inaccuracy of oil meters, particularly for a small flow under heavy pressure. It is generally conceded that there is no meter that will accurately determine the oil consumed by a single small furnace.

Barnes [a] testifies to this lack and suggests putting two meters in series, adjusting them to read the same under all conditions that the system will have to meet, pumping a large quantity of oil through both, taking off the supply to the furnace between the meters, and passing the oil from the second meter back to the pump. This procedure involves pumping much more oil than is needed, and might not serve in a system in which the oil is forced by air pressure instead of by a pump.

A reliable oil meter is therefore needed for general work as well as for efficiency tests of single furnaces.

SOME FURNACE PROBLEMS AWAITING SOLUTION.

There are certain points of both scientific and technical importance on which more detailed knowledge would aid investigators of brass-furnace design and brass-furnace efficiency. First among these, of course, should be named further knowledge as to the properties of known alloys and the effect of impurities on them, as well as the discovery of new alloys.[b]

Other problems, the solution of which would help reduce waste and increase efficiency, are the determination of the proper pouring temperature for various alloys and of the actual amount of heat required to raise various alloys to a proper pouring temperature; development of better refractories for furnace linings; further knowledge as to fluxes and molten covers, and as to "reducing," "neutral," and "oxidizing" atmospheres in brass furnaces. Although the terms "reducing flame," "reducing atmospheres," "oxidizing flame," and "oxidizing atmosphere" are commonly used, and have been used throughout this bulletin to express the idea in mind, yet there is no exact knowledge as to what constitutes a reducing or oxidizing atmosphere in a brass furnace. Wider knowledge as to the waste gases from various types of furnaces as well as of the fuel consumption, metal loss, speed of melting, and the quality of the metal produced when the furnaces are run under more and less strongly oxidizing and reducing conditions, would contribute much toward better furnace operation.

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[a] Barnes, E. A., Nonferrous foundry economics and refinements: Trans. Am. Brass Founders' Assn., vol. 5, 1911, p. 98.

[b] Whitney, W. R., Alloys: Trans. Am. Brass Founders' Assn., vol. 5, 1911, p. 54; Parsons, C. L., Notes on mineral wastes: Bull. 47, Bureau of Mines, 1912, p. 28.

ADVANCES POSSIBLE WITH PRESENT EQUIPMENT AND KNOWLEDGE.

Although further progress in the development of methods of heating and improvements in furnace design and furnace accessories, as well as the scientific solution of many problems, is desirable, there are yet great advances possible in the use of the equipment and knowledge now available. Pick out any alloy and any type of furnace and note from the table of data the vast difference in metal losses, in speed of melting, in crucible and lining life, and in fuel consumption between the average practice and the best practice as there shown.

The improvements possible in the present average practice may be divided into the utilization or recovery of various wastes and the prevention of wastes.

UTILIZATION OR RECOVERY OF WASTES.

UTILIZATION OF WASTE HEAT.

The waste heat from brass furnaces has been utilized in several ways—for preheating the metal to be melted, for annealing crucibles, for preheating air for combustion, for preheating oil or gas fuel, for heating core or mold drying ovens, for foundry heating, for heating a steam boiler and thus producing power, and for preheating the water fed to the boiler.

The use of waste heat for preheating metal is found to some extent in many foundries. In rolling mills it is common practice to lay some of the ingots of copper on top of the coal around the crucible in order to preheat them before putting them into the crucible. With tilting-crucible oil furnaces or with other types in which there is a charging opening, ingots, gates, or large pieces of scrap are often laid over the opening to be preheated by the waste gases. This heating also allows the breaking up of gates that are too long to permit ready charging, as they become brittle when hot and may be easily broken as they are being poked into the crucible with a bar.

Another very common use of waste heat is for heating the storage space for crucibles, which may be a special oven heated by running the main flue through it, or the crucibles may merely be piled back of a battery of furnaces or over the flue.

One maker of crucibles says: "The best device for annealing crucibles is a furnace built expressly for the purpose, using the waste heat from the melting furnaces on its way to the stack. These can be built so that the heat can be regulated and the temperature brought gradually up to or above 250° F."

With gas, oil, or forced-draft tilting coke furnaces the ladles may be inverted over the tongue of flame at the top of the furnace and thus heated before the metal is poured into them.

The next step is the use of a "feeder" or "hood" preheater. This is often an old crucible with a hole punched in the bottom and is set into the top of the melting crucible, being supported by it in pit furnaces or by a special holder or cover ring in tilting-crucible oil furnaces or tilting forced-draft coke furnaces. Nearly all of the latter are regularly built for a feeder, either an old crucible or a special funnel-shaped device of iron lined with a suitable refractory being used. In a foundry where crucible melting is done such a feeder is much used in refining borings into ingot, as it allows the charging of a greater quantity of borings than can be charged into the crucible without the feeder. The firm supplying Reply 14 uses a feeder in melting borings in both oil-fired and coke-fired pit furnaces. In Reply 6, representing a plant that uses a tilting, forced-draft coke furnace, it is stated that the metal is actually melted in the preheater, dropping into the crucible proper, where it is brought to pouring temperature. The high fuel efficiency of the tilting, forced-draft coke furnace is partly due to the use of the preheater.

Some double, reversing, oil, or gas furnaces are designed with two crucibles or chambers, a burner being placed at each end, and metal is put in both crucibles or chambers, but only one burner is used at a time. The waste gases from the first compartment pass into the second before leaving the furnace, thus preheating the metal in the second. When the metal in the first one has been melted it is replaced by a cold charge and the other burner is lighted. The preheated metal in the second and now primary chamber is melted more quickly than if it had not been preheated.

This reversing principle is applied to both open-flame and crucible furnaces. Many users of this reversing method of open-flame heating have abandoned it on account of the rapid deterioration of the furnace lining, which, however, is a fault of the construction of the furnace rather than inherent in the method (see note on Reply 187). The three replies (Nos. 73, 96, and 204, subdivision 32, of the large table) from firms using the open-flame reversible furnace show a rather better average fuel efficiency than the general average of the single-chamber furnaces of the same size.

No data are available on crucible furnaces of this type, but one maker claims a 25 per cent saving in oil or gas by its use. Best [a] describes an oil-fired reversing furnace for brass melting that takes three crucibles in each of two chambers. Each chamber becomes in turn the melting and the preheating chamber. This furnace is said [b] to be in successful operation.

[a] Best, W. N., The science of burning liquid fuel, 1913, p. 130.

[b] Best, W. N., op. cit., title-page.

In another method of construction applicable to pit furnaces a second crucible is set into a second pit, into which the flue from the furnace proper leads and from which a flue leads to the stack. The second pit may therefore be regarded as an enlargement of the flue. The metal in the second crucible is preheated by the waste gases until the metal in the primary chamber is ready, when the first crucible is replaced by the second one with its preheated contents. After the metal in the first crucible has been poured that crucible is charged anew and returned to the furnace, but this time to the secondary chamber.

Such a furnace heated by oil is described by Krom [a] who states that the metal in the secondary crucible may be preheated to 800° or 1,000°. (It is not stated whether this temperature is in centigrade or Fahrenheit degrees.) He gives no figures as to the saving in fuel.

Reply No. 60 (subdivision 6 of the large table) gives data on the use of such a furnace fired with coke and coal under forced draft, the air supply to both chambers being under regulation. In this case the pouring temperatures used are high, and the metal in the preheating chamber is brought almost to the melting point, or even above it, before the metal in the primary chamber is ready to be poured. The fuel consumption reported on this furnace is high, but the metal has to be much hotter than in ordinary practice, and the report is on a square furnace. It is stated that better results had been previously obtained with a round furnace. The user states also that the preheating of the metal gives a far greater efficiency than can be obtained without it.

A similar enlargement in the flue of a pit furnace is used to heat pouring crucibles used as ladles for tilting furnaces in some other foundries where both pit and tilting furnaces are in use.

Another method of utilization of waste heat is for preheating the air for combustion in forced-draft coal or coke or oil or gas furnaces, and for preheating the gas or oil fuel as well. Such utilization is usually effected in one of the following ways: The air pipe is run through the exhaust flue, care being taken that by the use of suitable by-passes only enough hot gases are admitted to heat the pipe to such temperature as it will stand without too rapid deterioration; or the air pipe is run in a spiral, or in a series of return bends, in the path of the waste gases from a tilting furnace; or the air is passed around the furnace shell and within an outer shell (with such an arrangement the refractory furnace lining need not be as thick as usual) before it goes to the fire box of a forced-draft furnace, or to the burner of one fired with oil or gas.

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[a] Krom, L. J., Development of melting furnaces: Metal Ind., vol. 7, 1909, p. 325.

Oil may be heated in similar ways, but can not be heated hot enough to effect much real fuel saving, as too high a temperature will cause the deposition of carbon, which will clog the burner. Preheating of oil is mainly to make it fluid enough to flow more readily and to atomize more easily.

The firm supplying Reply 10 preheats both the oil and the air for combustion. Reply 15 is on natural-gas pit furnaces with air preheated by being passed around the furnace shells. Reply 108 is on a city-gas pit furnace, and Reply 164 is on pit furnaces fired with producer gas, in both of which regenerative heating is used. In the first furnace the temperature of the waste gases leaving the regenerator is said to be 200° F., and in the second the incoming air is said to be preheated to about 600° F., the air pipes being kept just below a visible red. In the latter furnace there was considerable difficulty at first in getting a grade of iron pipe and a method of making expansion joints that would prevent the necessity of frequent repairs to the recuperator, but the trouble was overcome.

Reply 152 covers a tilting oil furnace in which the air pipe leading to the burner was given a number of return bends as it passed through the hood over the furnace that carries off the return gases. The oil pipe is similarly placed, but not in so hot a place. The air, by the time it reaches the burner, is heated to 600° F. and the oil to 375° F. This furnace shows a high fuel efficiency. The same firm also uses a forced-draft, tilting, coke furnace for which the air is heated as in the oil furnace, and also by being passed around the furnace shell before going into the fire box, thus being heated to a higher temperature than the air for the oil furnace. The fuel efficiency is below the average, but may perhaps be due to having too large a coke space.

Several methods of preheating the air for combustion, as well as the use of preheaters and feeders, are described by Horner [a], who states that furnaces utilizing waste heat are 50 per cent more efficient than the ordinary pit furnace.

An English furnace of the forced-draft tilting coke type in which the air is preheated, both by being passed around the furnace shell and by being brought to the furnace by an intake pipe bearing a helical fin and running through the flue that carries the waste gases, is shown by Horner,[b] and by Marteil.[c] The helical fin forces the waste gases to whirl around the intake pipe, an arrangement that is intended to produce a greater preheating of the incoming air by lengthening the path of the waste gases about the intake pipe. A feeder is also used on the furnace.

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[a] Horner, J., Utilizing the waste heat from brass furnaces: Foundry, vol. 41, 1913, p. 113.

[b] Horner, J., loc. cit.

[c] Marteil, V, Alliages et fonderie de bronze, 1910, p. 97.

Reynolds[a] advises preheating the air supply in open-hearth furnaces for melting iron by the waste gases and claims that this would effect a saving of 25 per cent of the coal.

One type of oil-fired converter for steel preheats the air used for combustion by directing the tongue of flame issuing from the "nose" of the converter into an economizer. The maker of this converter states:

This economizer is an important feature of the plant, serving to recover the waste heat arising from the combustion of the oil during melting. It consists essentially of a series of ribbed cast-iron pipes of U-section, through which the blast passes, the heat from the vessel passing round and amongst those pipes on its journey to the chimney. By this arrangement the cold air delivered from the blower is raised to a temperature of about 800° F. before passing to the converter.

This device should be directly applicable to open-flame brass furnaces fired with oil or natural gas.

It may be confidently stated that any of the preheating devices mentioned will considerably increase the fuel efficiency over that possible without such preheating. Whether the saving will pay for the cost of installing the necessary additional equipment and of repairs is a question depending on fuel cost, the degree of perfection of the preheating device chosen, and the special conditions in the individual plant. In general, the use of preheating devices manifestly means a considerable saving.

The above methods of utilizing waste heat are somewhat directly connected with the heating of metal, crucibles, and ladles; that is, except for crucible storage, when the need for the heat exists only when the furnaces are running.

Besides these methods, there are other ways of utilizing waste heat. One of these is in heating ovens for baking cores or dry-sand molds. This use has been suggested by Langdon.[b] Barnes[c] in this connection writes as follows:

In our foundry we have arranged the store room for crucibles, fire-brick beds, and other supplies that are likely to be affected by the absorption of moisture in a brick vault heated to a considerable degree by the passage of spent furnace gases through suitable ducts under the floor of the vault. Shelving is arranged in this vault for the storage of cores that have been baked but are not yet required. For a number of years we have successfully employed a core oven built in line with the main flue-gas vent. The spent gases from the furnaces pass through cast-iron ducts built to constitute the floor of the core oven. These ducts are controlled by hinged dampers which can be deflected so as to pass the gases directly up the stack. When it becomes necessary to bake large cores, the heat in this oven is augmented by the use of an oil burner connected to the main fuel system.

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[a] Reynolds, A., Some fundamental faults of the present-day furnaces and their remedies: Iron and Steel Inst., May, 1913, meeting, reported in Met. Chem. Eng., vol. 11, 1913, p. 413.

[b] Langdon, P. H., The use of brass-foundry gases: Met. Ind., vol. 5, 1907, p. 356.

[c] Barnes, E. A., Nonferrous foundry economies and refinements: Trans. Am. Brass Founders' Assn., vol. 5, 1911, p. 65.

The firm supplying Reply 10 uses such an oven for baking dry-sand molds, and reports as follows:

While we used the waste heat from our pit furnaces in the old foundry to fully heat our core ovens, the gases passing directly through it, in our new foundry, where the smoke bonnets and other ventilating arrangements were piped into the same core oven, the amount of cold air passing in seriously interfered with the heating effect of the ovens themselves. For this reason we abandoned this arrangement, although if we had put up a separate stack for ventilation and allowed the waste heat from 12 or 14 furnaces to go through the oven we would no doubt have ample heat. These gases are used now in a measure to keep our crucible storage warm and dry, but there is no doubt that with a properly arranged furnace room the wash water and the core ovens could be satisfactorily heated.

The firms represented by Replies 48, 101, 122, and J, which use natural-draft, pit, coke furnaces, and the firm represented by Reply 146, which use pit oil furnaces, heat core ovens with the waste gases.

The core ovens heated by the coke furnaces are small ones, directly over the main flue, which has a thin top so as to give as much heat as possible to the ovens. The temperature at which the cores are baked in the oven is regulated by the distance the shelves bearing the cores are placed from the floor, or by varying the supply of air. In oil furnaces, the waste gases are passed directly through the core oven on their way to the stack.

In shops requiring little core work such arrangements are quite satisfactory. In putting such a system of core-oven heating into a shop where the core work is an important factor and oven room not too plenty, some auxiliary method of heating the ovens should also be installed, because, although too strong a heat can be prevented by by-passes and dampers, if enough furnaces are not being run on a given day to bring the oven to the right baking temperature, important cores for the next day's work may be left green, or cores of a poor quality may be produced through inability to get the proper baking temperature for the binder used.

If an auxiliary oven-heating system is ready for use whenever the waste gases do not supply enough heat, waste-gas heating should prove satisfactory, and should almost eliminate the item of expense for core-oven fuel.

Still another use for the waste gases is in heating the foundry in cold weather. It is a crying shame that so many foundries are so cold in winter that the men can work with neither comfort nor efficiency, and that the sand is cold or even frozen, so that the castings show blowholes and other defects due to cold sand, although more unused heat is passing outdoors in the waste gases from the furnaces than would heat the foundry well. There are two desirable methods by which such foundry heating might be accomplished—by indirect-air heating, or by steam or hot-water heating.

The indirect-air heating, obtained by putting a casing around a sheet-iron section in the base of the stack and blowing the air to be heated through the space between the stack and casing, is said [a] to give satisfactory results in annealing furnaces and is suggested for brass furnaces.

Some devices, in which the air was passed through iron pipes placed in the base of the stack, have not given satisfaction in this country on account of the destroying of the pipes by the heat and the sulphur dioxide from the fuel used. One firm, which uses a dozen pit, coke furnaces taking a No. 80 crucible, had such experience and reports as follows:

A description of what we endeavor to do with our waste heat from the brass furnaces, and which did not prove satisfactory, follows:

In building our new plant we constructed a chimney which is a circular affair inside and out, 36 inches on the bottom and 24 inches on the top, 60 feet high, with two inlets—one on the floor level and one about 12 feet from the floor. The openings are 90° from each other. The air channel from the brass furnaces leading into a chimney on the floor level was connected with a shut-off at the chimney and also had a shut-off in the middle of the air channel. We had a hot-air furnace made by an engineering company who claimed they had the only apparatus in the market for handling hot gases which could not be utilized for heating.

This furnace consists of a series of cast-iron tubes about 4 inches in diameter and 4 feet long. These were inserted into cast-iron plates on either end, and asbestos packing was inserted round the tubes on the inside of the plates, and this again held tight by a spring cast-iron washer to make it air-tight. On the front end of this furnace we had a 6-foot fan which blew the cold air into the inside of the tubes and would come out hot on the other end, which then went through the air duct throughout the factory. Beneath these tubes we had also a furnace whereby we could heat the tubes independent of the waste heat from the brass furnaces, as for instance, at night the furnaces are not in use and the night watchman had a fire in this furnace. In the day time or about 7.30 when the furnaces were all going we opened up the damper in the furnace channel and let the hot air from the furnaces pass through this furnace on the outside of the tube and up to the inlet in the chimney, about 12 feet from the ground. When this was running the shut-off or damper on the floor level to the chimney was shut off. In the evening when we were through melting, the damper or shut-off in the furnace was shut off and then we opened up the damper connected with the inlet of the chimney.

This system worked well in moderate weather, but we had this put in two years ago, and the first winter we tried it we had an exceptionally cold winter and it did not work satisfactorily at a temperature on the outside to more than 10° below zero. When the temperature on the outside got lower than that, we could not heat the factory properly.

A second objection, and this was probably the main reason we gave it up, was that the company had guaranteed the tube to stand several years without burning up. They claimed they had experimented on this for years and had a perfect mixture in iron which would stand the excessive heat on the outside and approximately cold influx of air on the inside without cracking. It proved, however, that these cast-iron tubes cracked the same as any other cast iron, and whenever they cracked it left a certain amount of gas in the factory, which was objectionable. During the corre-

[a] Boeddicker, G. A., In discussion at a meeting of the Birmingham Section of the Institute of Metals, reported in Brass World, vol. 9, 1913, p. 13.

spondence with the firm asking for remedy, they went into the hands of the receiver. When the winter was over, the writer decided not to try this again for another winter, and we have now installed a heating plant with a low-pressure steam system and having about 7,000 feet of radiation on an area 7 feet by 8 feet by about 6 feet high, and the same fan is used to blow the cold air through the pipe and force it through the factory as before. This system we think is by far the better, because it distributes fresh air from the outside heated to the proper temperature throughout the plant all the time, and by having steam coils up above the boiler the condensed steam goes back into the boiler again as hot water, without any pumps or traps of any kind.

However, as iron piping, if not in too hot a place, gives satisfactory results in regenerative gas furnaces, the method ought to be possible, at least with some fuels. Heating by hot water or steam will of course keep the piping cool enough to insure a good life. Reidenbach [a] states that the waste gases from the furnaces of open-hearth steel mills contain enough heat to generate sufficient steam for the operation of large plants and that he himself, with the waste heat of two No. 200-crucible pit furnaces, has maintained a steam-heating plant carrying heat to the entire offices, at an annual saving of $300 in fuel.

One plant visited had tried such a method, a small boiler being placed over the main flue from a couple of pit furnaces, the flue taking the place of the ordinary fire box and furnace of the boiler. This arrangement worked well while the furnaces were in constant operation, but was abandoned because the operation of these furnaces became intermittent. However, an auxiliary fire box might have been added.

In another plant visited by the author, waste heat successfully heats a large foundry with several wings of a high one-story construction and with a great many windows. Pit, coal furnaces, in a large battery, with large main flues leading to the stack, are used. The flues have doors at their ends which allow access to the interior. Three or four return bends of 3-inch pipe some 15 or 20 feet long are placed within the main flue when cold weather begins and are connected with radiator pipes running all over the foundry. The arrangement is very similar to the common method of heating water for household use in an ordinary hot-air furnace.

The foundry is said to be well warmed in the most severe weather, no frozen sand being found, even near the windows farthest from the furnaces. The piping is removed in the spring, when foundry heating is no longer needed. The same pipes have been used for three years and appear to be still in excellent shape. Everyone around the plant was enthusiastic over the success of the system.

In plants dealing with high-zinc alloys any method of utilizing waste heat should allow ready access to any part of the system, thus

[a] Reidenbach, F. W., Waste heat: Trans. Am. Brass Founders' Assn., vol. 3, 1909, p. 17; Metal Ind., vol. 7, 1909, p. 219.

permitting the removal from time to time of any zinc oxide that might collect on the pipes and, by insulating them to a degree, cut down the amount of heat furnished.

The chief remaining method of utilizing waste heat is in steam raising for power purposes, or in preheating water fed to the boiler of the power plant.

The use of inclined or vertical water-tube boilers, economizers, and feed-water heaters in the stacks of open-hearth steel furnaces, puddling furnaces for melting iron, and reverberatory copper-melting furnaces is generally well known. A paper [a] on the generation of steam by the waste heat from furnaces was presented at the October, 1913, meeting of the Iron and Steel Committee of the American Institute of Mining Engineers.

The waste gases from cement kilns have also been used for steam raising.

Schreiber [b] describes the use of such devices in connection with open-hearth steel furnaces and the use of waste heat in reverberatory copper-melting furnaces is shown by Mathewson.[c] It is stated [d] that heat losses may be reduced 40 per cent in open-hearth furnaces by the use of the waste gases. Peters [e] states that boilers of about 600 horsepower are used between reverberatory copper-melting furnaces and the stacks, usually two boilers per furnace being installed. By this method, when the furnaces are fired with soft coal, one-third the total heat value of the coal used is recovered as steam, the temperature of gases being reduced from between 950° and 1,000° C. (1,730° to 1,830° F.) to 350° C. (660° F.) by the boilers. Douglas [f] states that on reverberatory copper furnaces 45 to 55 per cent of the heat of the fuel is recovered as steam, and that to this recovery is due the low cost of smelting attained. On oil-fired reverberatories practically half as much steam is made by the waste gases from a pound of oil after passing through the reverberatory as would be made if the oil were burned directly under a boiler, the waste gases being reduced from 1,150° C. (2,100° F.) to 400° C. (750° F.) It is also said [g] that some of these waste-heat boilers have been in use in copper furnaces for five years before being reset.

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[a] Stone, G. C. Note on utilization of waste heat of regenerative furnaces: Bull. 82, Am. Inst. Min. Eng., 1913, p. 2410.

[b] Schreiber, J., Use of waste heat from the Siemens-Martin furnace: Stahl und Eisen, vol. 33, 1913, pp. 45, 107.

[c] Mathewson, E. P., Development of the reverberatory furnace for smelting copper ores: Proc. 8th Int. Cong. App. Chem., 1912, vol. 3, p. 133.

[d] Anon., The use of waste heat on open-hearth furnaces: Iron Age, Feb. 20, 1913; Eng. Mag., vol. 45, 1913, p. 149.

[e] Peters, E. D., Practice of copper smelting, 1911, pp. 314, 328, 329, 339, 361. See also Sorensen, S. S., Waste heat boilers in reverberatory furnace flues: Min. Sci. Press, vol. 107, 1913, p. 575.

[f] Douglas, J., The relative importance of principles and practice in education: Met. Chem. Eng., vol. 11, 1913, p. [illegible].

[g] Mineral Industry, 1911, p. 216.

Although the savings shown on brass furnaces might not be as great, they should be considerable. One firm states that it tried a hot-water coil for heating boiler feed water in one of the stacks from its natural-draft coke furnaces, but found that the coil interfered with the draft. Another firm that uses pit oil furnaces was designing a boiler, of the vertical type, for use with waste gases. This was to be in several sections, so that those sections normally taking the gases from any part of the battery that might not happen to be in use might be cut out of the circuit. The boilers were to be in series with the main boiler of the power plant and were expected to reduce the stack temperature to 300° F. The furnaces might be converted from oil furnaces to forced-draft coal furnaces at any time that fuel costs might make the change desirable and the boilers were expected to work equally well when the furnaces were run on either fuel.

Another firm writes as follows:

> We have seven pit furnaces burning anthracite coal under forced draft. These are placed on either side of a 100-horsepower boiler, and the waste heat from the furnaces is led directly below the boiler. We can not estimate how much this saves us in the way of fuel for the boiler; all we know is that we are using only 1½ tons of Pocahontas coal per 10-hour run to obtain upward of 100 horsepower. We see an additional advantage in disposing of the waste heat from the brass furnaces in this manner, in that the furnace tender's occupation is rendered more bearable because of the comparatively small amount of heat above the brass furnaces.

It is therefore seen to be quite possible to utilize by one or more of the above methods much of the waste heat from almost any type of furnace. The main precaution that has to be observed in the cases where the waste heat is used for other purposes than for preheating metal or the air for combustion is not to attempt to use the waste heat as the only source of heat when a constant heat is required and the furnaces are only intermittently used, or when close regulation of temperature is necessary.

RECOVERY OF COAL OR COKE FROM ASHES.

If coal or coke furnaces can not be run so as to burn the fuel completely, there is a possibility of recovering some of the unburned fuel from the ashes. In some plants visited so much unburned coal went through the grates that the ash pile was almost as black as the coal pile.

Several plants report that the ash is roughly riddled and picked by hand, any good fuel, as well as any large pieces of metal, being picked out, and that such hand picking is profitable. One plant finds that partly burned coal, owing to its freedom from moisture, can be satisfactorily used for the bed of the first heat in a pit furnace.

Peters[a] states that of 114,000 pounds of soft coal used per 24-hour day per furnace in a big smelter, 26,000 pounds of coal and coke is recovered from the ash by jigging. The recovered fuel is briquetted and used. Recovery of combustible material from ashes by flotation in liquids of different specific gravities has also been suggested.[b]

USE OF BORINGS.

There is a difference of opinion as to whether borings or other small pieces of clean metal produced in manufacturing operations within the plant should be used in the regular furnace charges, or should first be run into ingot, no fine material being used in the regular charges.

The running of borings into ingot means an extra melting of the ingot before the metal can be run into castings, with consequent cost for fuel, labor, and lost metal. The majority of the manufacturing plants reporting use from 15 to 25 per cent of their own borings in the regular charges, as is shown by the entries in the large table under the heading "Composition of charge."

Some few jobbing foundries also use borings almost entirely, buying new metal for alloyed ingot only for castings that must meet exact chemical or physical specifications.

When borings are used, much mechanical loss may result from carelessness in charging the borings. The bottom of the crucible or furnace chamber is usually first charged with a small quantity of borings, gates and heavy scrap being placed on top of the borings and ingot metal on top of the gates. In open-flame furnaces the whole charge of borings may thus be put at the bottom. In crucible furnaces part of the borings must be charged after the melt has been run down enough to leave room in the crucible. The charging of borings, especially in too small crucibles, is often attended with much spilling of the borings on the floor and into the coke or coal space, or combustion chamber, of the furnace outside the crucible. The spilling may be somewhat avoided by care in charging, by supplying proper scoop shovels, and by using a sheet-iron funnel set into the top of the crucible. If the draft is strong, very light borings may be actually carried into the flues and thus lost. The borings lie on top of the molten metal and unless continually poked down will lose some zinc even before melting, and if the atmosphere is oxidizing will oxidize badly on account of their large surface.

For these reasons, coupled with the likelihood of borings of varying compositions being present, if care is not taken in the machine shop to keep borings from different alloys separate, some of the larger plants consider that the best results are obtained by running the

[a] Peters, E. D., Practice of copper smelting, 1911, p. 414.

[b] Luhr, A. F., Recovery of coke from ashes: Jour. Ind. Eng. Chem., vol. 5, 1913, p. 425.

borings down into ingot in large furnaces, usually either reverberatory or open-flame. Each charge of ingot is then analyzed and the proper charge of boring ingot, new metals, gates, etc., determined on the basis of their analyses.

Some of the smaller foundries that do not wish to use borings in their regular work find it best to sell the borings to a refinery. Whether it is cheaper to ingot borings at the plant using them or to sell them will depend on the quantity of borings produced and the location of the plant.

Oily borings should be treated in a centrifugal oil extractor in order to save the oil and to put the borings in better condition for being melted.

BRIQUETTING OF BORINGS.

If clean borings or similar fine material could be agglomerated into solid masses that would not fall apart on being charged and would sink beneath the surface of molten metal, it would seem that they should be melted with little, if any, more loss than occurs with ingot metal. In refining impure borings they are sometimes made into briquets, a binder, such as lime or pitch, being used to some extent, but briquets made of clean borings do not appear to have met with much success, the briquets disintegrating as soon as they become hot. Briquets made under such heavy pressure that the borings agglomerate without the use of a binder and become almost solid are now used.[a] The process has been developed mainly for use on iron, although its field should seemingly be much greater in connection with the more expensive nonferrous alloys. Briquetting has been tried in brass melting, but Reply 104 states that not enough saving in lost metal was effected over the charging of all the borings at the bottom of the furnace chamber to pay for the cost. For melting charges consisting entirely of borings, as in a refining plant, briquetting deserves at least a trial.

Sperry[b] states that yellow-brass chips thus briquetted can be melted with a loss of only 1½ to 2 per cent, whereas without briquetting, the loss is at least 5 per cent.

Wallace[c] reports an experiment in melting briquets of yellow-brass borings in which the melting loss was less than 3½ per cent.

Figures are given[d] showing that the loss on melting briquetted brass borings was 3 to 4½ per cent, and on aluminum borings 15.3 per cent. It was stated that the loss on the aluminum borings would

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[a] Sperry, E. S., Briquetting borings: Brass World, vol. 7, 1911, p. 41; Chem. Abs., vol. 5, 1911, p. 1251; Woods, C. F., Report of official chemist: Trans. Am. Inst. Metals, vol. 6, 1912, p. 4; Metal Industry, vol. 10, 1912, p. 405.

[b] Sperry, E. S. (In discussion): Trans. Am. Inst. Metals, vol. 6, 1912, p. 14.

[c] Wallace, R. B. (In discussion): Trans. Am. Inst. Met., vol. 6, 1912, p. 17.

[d] Editorial, Briquetting machine for metal borings and turnings: Engineering (London), vol. 94, 1912, p. 737; Jour. Inst. Met., vol. 9, 1913, p. 246.

have been about 50 per cent had the borings been melted without briquetting.

RECOVERY OF METAL FROM WASTE MATERIALS.

The recovery of metal from waste materials carrying considerable metal but too much other material to allow melting of the metal without a mechanical separation, or a refining melting somewhat along the lines of ore smelting, or both, is a problem that is receiving increasing attention in the most progressive plants.

Such waste materials are skimmings—metal mixed with slag and oxide—usually the richest form of waste material from the foundry; spillings from the ladles, which become mixed with molding sand; ashes from coal or coke furnaces into which metal has been spilled or dropped in charging; dust from emery grinders and saws; dust, including some fiber, from polishing wheels; mud, containing abraded metal from tumbling barrels; and old crucibles.

Some large plants retain a smelting and refining plant in connection with their regular work and get a large proportion of the metal they use out of wastes sold them by others.

In one plant visited by the author the superintendent said that a small neighboring foundry had been paying a cartman to carry away a pile of skimmings that had been accumulating for several months. The cartman sold the skimmings to a junk dealer for several hundred dollars. The junk dealer afterwards stated that he made a good profit as the material contained 60 per cent of metal. Such cases, happily, are rare. Many plants, however, closely approximate the case cited by selling a pile of skimmings at a lump sum without assay.

In this connection Jones [a] makes the following pertinent remarks:

> There are a few objections that are raised in some quarters to disposing of scrap to the smelter. One is that the small dealer will call for scrap and haul it away without cost to the brass founder, while if he is situated at a distance from the smelter the freight charges may be high. This is offset by the greater net profit that is nearly always obtained when selling on an assay basis and by the smelter's establishing local collecting points which thus eliminate the freight charges or reduce them materially. The small dealer has to pay cash against bill of lading, while in the past the smelters have delayed settlement until all assays have been completed. They are now willing, however, to pay three-quarters of the estimated value of the shipment immediately after it is shipped and the remainder promptly on completion of the assay.
>
> Many brass founders are dubious about selling on an assay basis because they are not familiar with the methods of sampling and assaying and the various calculations involved in arriving at the market value of scrap material. If they will devote a little time to the matter, they will find it is not such a formidable undertaking after all and that it will not require many assays to show them exactly what each grade of scrap they produce is worth, provided, of course, that their manufacturing methods are standard and not subject to frequent changes. On account of the loose and unbusinesslike methods of selling that have prevailed in the past, there is sure to be a steady

[a] Jones, J. L., The selling of brass-foundry refuse: Trans. Am. Brass Founders' Assn., vol. 4, 1910, p. 63.

increase in the number of those who dispose of their wastes on an assay basis. Even the firms that prefer the old methods are safeguarding themselves by having a sufficient number of assays made on all waste products to indicate their value. If the market value of a material is ascertained by having it assayed, competitive bids on it can then be better judged.

Every brass founder will find it to his advantage to get in touch with one or more reliable smelters and become familiar with their methods of doing business on an assay basis. He should also have a competent metallurgical chemist examine his by-products and report on their average copper content and market value.

The foregoing discussion deals with wastes of impure materials and those from which the larger pieces of metal have been removed. Material that is too fine or contains too much foreign matter to allow its melting without undergoing a true smelting operation must of necessity find its way to the smelter. As such waste is considered only as copper-bearing material and is paid for only on the basis of copper content, it is evident that if the plant producing the waste would separate the larger pieces of metal, so far as they can be obtained free enough from other material to allow direct melting, such separation would pay, as the full metallic content, less the melting loss, would be recovered instead of merely the wasted copper minus the smelting charge.

A rough separation of metal from skimmings and, usually, from ashes may be economically made by most foundries, and by many of those whose output is smaller than the owners now consider will justify such a separation.

METHODS USED FOR ROUGH SEPARATION OF WASTES.

Out of 230 answers to the list of questions, 102 made no reply to the question referring to the use of a concentrating system for wastes, the inference being that the waste is sold without concentration of any sort. There were 32 replies stating definitely that the waste was sold. Three replies state that skimmings are charged back with the next heat in order to free the entrained metal. Four replies state that the waste is hand picked, with or without riddling. One firm riddles and hand picks the waste after it has been crushed. Two firms state that each form of waste is sold, but that the sweepings, skimmings, spillings, ashes, emery dust, etc., are each carefully kept separate, the richer waste not being mixed with the poorer, a practice that results in getting a better price for the waste than if all the wastes were indiscriminately mixed. One firm states that it is too small to attempt concentration, and another that it has no room for the necessary installation, but both agree that concentration is desirable for most plants. Five state that some concentrating system is in use, without describing it at all. Three report that they run regular refining furnaces on the wastes

(probably after some concentration). One washes the wastes by hand in the river.

Most of the plants doing any concentration at all use merely a wet process, usually a ball mill with a stream of water running through it at such velocity as will carry off nearly everything but the larger pieces of metal. The overflow is run into a sump, and the tailings, after the water has soaked out, are either used for filling in waste ground, drawn away to a dump, or sold to smelters. Some firms report that the tailings are too low in copper content to be salable, although the separation is by no means complete. Others save only large pieces of metal by the process, the tailings being rather rich. One of these firms uses a tumbling barrel, charging the skimmings with the castings and running water through the barrel, the castings being used instead of balls to break up the slag. Four of these firms state that, although they use coke or coal furnaces and hence have ashes, skimmings and sweepings only are treated in the wet grinder, the ashes not being concentrated. One firm saves the waste and cleans it with a wet process once or twice a year.

Twenty-three replies show a further step in concentration, the wastes being crushed by rolls, jaw crushers, stamps, edge runners, or ball mills, and the crushed material washed through sluice boxes or into jigs, and thence to vanners or Wilfley tables, or through various combinations of these. Three other firms use air separation. By air separation the firm represented in Reply 191, which uses open-flame oil furnaces, recovers as coarse metal from the skimmings 0.83 per cent of the original charge by the use of a dry crusher, and a further 0.41 per cent of finer metal by exhaust-air separation. Another firm, using pit, coke, or coal furnaces, grinds all wastes in a ball mill through which a blast of air is blown. The heavy pieces of metal remain in the mill, and the fine metal, ash, etc., are blown through a large settling house, which catches some of the fine metal. Another firm first uses a wet ball mill for separating the large pieces. The tailings are then dried and ground fine without water; they are then dropped from a hopper down a pipe into a settling box. A blast of air enters one side of the settling box and carries off the lighter particles, the metal particles remaining in the box.

Air separation is not used nearly as much as water separation, and the air method has been replaced by the water methods in several plants visited. In many of the more complete systems of water separation the water is run from the sump where the tailings are collected into a settling tank. The water is pumped over again by a centrifugal pump if water charges are high.

One rolling mill uses a wet ball mill, the overflow passing through a Huntington mill, then to a vanner. It is estimated that as much is recovered by the vanner as by the wet ball mills. One foundry uses

first a crushing barrel, passing the crushed material through a trommel with a water jet over it and then into a Hartz jig. Much of the ash, etc., is swept away before reaching the jig, the tailings from which contain 6 per cent of metallic oxides and 3 per cent of fine metal.

One rolling mill first picks the wastes by hand to recover large chunks of metal and unburned fuel, then uses a jaw crusher, then a Huntington mill, and then Wilfley tables. Another mill uses edge runners for crushing and jigs for concentrating. Still another uses edge runners, followed by treatment in simple sluice boxes, the overflow from which is carried to two Wilfley tables. The tailings from these contain only 0.25 per cent of copper, all of which is said to be in the form of oxide or silicate, and none metallic. This plant prefers edge runners for crushing, as they are thought not to crush the metal and to reduce the size of the metallic particles as much as ball mills, the stamp mills being considered particularly wasteful in this respect. Over half the recovery is made in the sluice boxes, and the metal there recovered is large enough and free enough from foreign material to go back to the furnaces. The metal recovered from the Wilfley tables is said to contain 30 to 35 per cent of copper, and, being thus impure and very fine, has to go to the smelter.

The more complex installations of concentrating machinery are chiefly in large plants, such as rolling mills, which use pit, coal, or coke furnaces. One rolling-mill chemist stated that untreated ashes from rolling-mill pit furnaces have an average copper content of 1 per cent; another put it at 0.5 per cent.

Skimmings unmixed with ashes usually give tailings from the wet grinders rich enough for sale to smelters. One firm using pit, oil furnaces, and crushing the skimmings in a wet ball mill reports 3 to 5 per cent of copper in the tailings.

Hughes,[a] in describing English practice, mentions that dry riddling and hand picking of all wastes, followed by wet grinding, is employed.

Seipke,[b] in an article on German practice, in concentrating brass-foundry wastes, states that in Germany most foundries themselves recover the bulk of metal in large enough pieces and sufficiently free from foreign material to allow its addition to ordinary charges, wet ball mills being used and having supplanted wet stamp mills. The tailings go to smelters or to the smelting departments of the large plants. They are made sufficiently fine by being put through dry screens and ball mills, from which some metal clean enough for crucible or reverberatory furnace melting is obtained. The recovered metal is run into ingot. Then a pulp is made with water and

[a] Hughes, G., Nonferrous metals in railway work: Jour. Inst. Metals, vol. 6, 1911, p. 96; Metal Industry, vol. 9, 1911, p. 463; Castings, vol. 9, 1911, p. 13; Foundry, vol. 39, 1911, p. 463.

[b] Seipke, F. W., Die Verhüttung Kupperhaltiger Industrieabfälle Metallurgie, vol. 9, 1912, p. 121.

passed through sluice boxes to shaking tables, the water being returned by centrifugal pump. The concentrate is then briquetted with lime and smelted in a blast furnace for its copper content.

Apparatus for concentrating systems,[a] of a complexity varying with the class of wastes to be handled and its amount, and especially designed for use with brass, are on the market. The apparatus vary from a set of crushing rolls, an elevator, a couple of jigs, and a centrifugal pump, for concentrating skimmings, dirty borings, etc., or some crushing device, a sluice, and a Wilfley or similar table for ashes, tumbling mud, emery dust, etc., to a system using both jigs and concentrating tables, and up to a complete and elaborate installation such as is described by Wittich.[b] This consists of a revolving trommel, the coarse material from which goes to a picking belt for the recovery of unburnt fuel and large pieces of metal, and thence to a crusher, the fines going through a system of single jigs and dewatering cones which produce a concentrate of 25 to 30 per cent of metallic content. The combined material then passes through crushing rolls and a screen to another system, embracing two-compartment jigs, and thence to concentrating tables. The wastes put through this carry 3 to 5 per cent of metal.

The mechanical appliances used for crushing the waste and separating the metal are rather similar to those used in the crushing and concentrating of ores, which are described in considerable detail by Hofman.[c]

In the plant where the waste is produced, it is certainly advisable to collect all the pieces of metal that are large enough to be remelted readily and are without notable admixture of foreign material, because, besides the copper, the other constitutents of the alloys are thus recovered. The recovery seems to be best accomplished by the use of some crushing apparatus, a wet ball mill for example, followed by a jig, or, at least, sluice boxes.

The tailings from such a recovery, containing about half the original metallic content of the waste, have to go to the smelter. Whether it will pay to concentrate the tailings in the plant producing them depends on the quantity of such material and the location of the plant producing it. In some localities, the tailings from small foundries using a fuel that produces no ashes, so that skimmings, sweepings, and grindings make up most of the waste, will probably be rich enough to warrant selling them without concentration, inasmuch as their quantity may not be enough to justify the installation of separating tables, or vanners.

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[a] Anon., Concentration of brass-foundry wastes: Foundry, vol. 40, 1912, pp. 9?, 495.

[b] Wittich, L. L., Recovering brass from foundry cinders: Eng. and Min. Jour., vol. 95, 1913, p. 851; Jour. Ind. Eng. Chem., vol. 5, 1913, p. 512.

[c] Hofman, H. O., General metallurgy, 1913, p. 534, et seq.

In plants having ashes the situation is different. Their tailings are bulky and of a low copper content. Also the value at the smelter of a pound of copper in copper-bearing material is much less when mixed with, say, 99 pounds of ash, than when mixed with, say, 40 to 60 pounds of ash. As freight charges to a distant smelter on low-grade material are high per pound of copper contained therein, and as the copper-bearing material is at one time flowing out of the jig or sluice boxes ready to go on a separating table or vanner, it is probable that most ash-producing foundries, even though they may run only half a dozen furnaces and use the concentrating table or vanners only a few times a year, will find that it will be to their advantage to effect the separation of the smaller particles of metal before selling the low-grade tailings.

Local conditions may operate against such separation, but it is certain that a more general use of separating tables or vanners than is made at present would be advantageous. Several cases have been noted in which the use of Wilfley tables or similar separating devices on low-grade waste, too poor to bear shipment to the smelter, has paid extremely well. Their use is the rule rather than the exception in rolling mills.

Parsons [a] cites a plant in which one experimental Wilfley table saved $80 a day. One foundry visited had recently installed tables and was working up at a handsome profit a large pile of sweepings that was too low in metallic content to warrant freight charges to the nearest smelter and would have required carting away at considerable cost had the table not been put in. Another plant visited had in previous years made merely a rough separation by crushing and washing. The tailings, too poor for sale to a smelter, had been drawn out in the yard. After the more complete concentrating system had been installed excavation for a new building was begun in the yard, and on trial the excavated material was found to contain enough metal to pay many times over for its concentration; hence the yard is being worked as a brass mine. Neither of these plants has any ashes to contend with, yet tables are found valuable.

Reply 16 (subdivision 1 of the large table) cites an example of a good recovery made with a complete concentrating system. The gross melting loss is given as 3 per cent and the net loss as 0.5 to 0.6 per cent. The 3 per cent figure for the gross loss is common, but such good recovery is not shown by plants with a less complete system. The rolling mills' figures in the table in general show a good recovery, owing to the use of complete recovery systems.

Refuse from the exhaust of polishing wheels and sweepings from wooden floors containing splinters, or any waste containing much

[a] Parsons, C. L., Discussion in mineral wastes symposium: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 155.

combustible material, may be purified by burning the combustible material in muffle furnaces [a] and subjecting the residue to wet concentration.

Sperry [b] decries wet washing of skimmings, claiming that all the oxides and fine metal are lost, and recommends that they be merely riddled through a 20-mesh riddle, that what goes through be saved (crushing is not mentioned, but must be involved to get the material to such fineness), and that what remains on the screen be picked by hand. This recommendation is evidently based on a comparison with a mere rough separation, without the use of tables. Hand picking of all metal larger than a 20-mesh fineness would seem a more laborious process than wet washing of the material left on the screen. If the proportion of oxide is high, dry riddling might be advisable, the fines going to the smelter for recovery of metal from the oxide and the rest being put through a concentration process, including Wilfley tables.

In a discussion on the treatment of the refuse in brass and copper mills Spittle [c] advocates keeping various forms of waste separate, whether they be concentrated in the plant itself or at a smelter. Earle did not consider that it paid a manufacturer to recover his own waste. Johnstone advocated putting ashes through a cupola or blast furnace without concentration. This view was strongly combatted by Sheppard, who said that such a procedure would cause the loss of all the zinc, and by Spittle, who said the raw ashes would choke the furnace and that wet concentration before smelting was preferable.

One firm describes their cupola-refining process as follows:

In our practice we make daily a large quantity of brass-foundry refuse which is composed of coke ashes, slag skimmings taken from our furnaces preparatory to pouring, fine emery-wheel grindings made in dressing castings, and fire-brick linings of all of our furnaces, all of which contain brass in different forms.

This is the material that we are charging into the cupola furnace. The furnace is 36 inches in diameter and contains a sand bottom 7 inches deep. On top of this there is a 9-inch cupola brick lining, and above this is a 4-inch water jacket. Into this we keep charging various ingredients as follows, the figures being approximate:

Ingredients:	Pounds.
Coke	120
Limestone	60
Rolling-mill cinders	15
Foundry refuse	400

We put the cupola into operation once a week for about two days, and we recover from it 600 pounds of metal and 600 pounds of slag per hour. Therefore, our total charge of refuse is about 2,000 pounds per hour, of which we recover 600 pounds of

[a] Sperry, E. S., Questions and answers: Brass World, vol. 9, 1913, p. 182; vol. 7, 1911, p. 34.

[b] Sperry, E. S., The treatment of skimmings in small brass foundries: Brass World, vol. 9, 1913, p. 70.

[c] Proceedings of meeting of Birmingham section of Institute of Metals (British), Dec. 10, 1912: Brass World, vol. 9, 1913, p. 49.

metal, or 30 per cent. It is operated with an air pressure of 12 ounces, using a blower operating at 240 revolutions per minute and supplying 8 cubic feet of air per revolution. The coke we use is 72-hour Connellsville.

The bottom lining of sand and the brick lining are replaced after each two days' run of 24 hours each. However, it would not be necessary to reline this so often if the furnace were kept in continual operation, as it probably would run for 6 days of 24 hours each.

The brass that we recover from this operation runs 74 to 78 per cent copper, 5 to 8 per cent tin, 4 to 6 per cent zinc, trace of iron, and balance lead, according to kind of material that we have been casting.

As a 30 per cent recovery is made from the refuse charge, it is evident that a preliminary concentration is made, although this was not mentioned.

A necessary part of the concentrating equipment is a magnetic separator for removing iron. The concentrated metal is usually dried in pans over steam coils or in ovens. The drying may be done by waste heat.

When the metal recovered by concentration is not too fine and is not too heavily loaded with foreign matter, it may be run into ingot instead of smelted for the mere copper content.

Fluxes advocated for the removal of foreign matter in such metal are glass,[a] sodium carbonate mixed with sand or lime,[b] lime, and fluorspar, and plaster of Paris.[c]

Concentrates high in impurities should probably be sent to the smelter, as one authority[d] advocates doing, but only, he advises, after a preliminary concentration.

The smelting of such material in the electric furnace without much metal loss and the recovery of other metals as well as the copper is an interesting possibility, and is said to have been done experimentally.[e]

One plant visited keeps all wastes from different alloys separate. Red brass, manganese bronze, and aluminum are the main alloys melted, and several separate receptacles for the skimmings are provided in convenient places, those for red-brass skimmings being painted red, those for manganese bronze yellow, and those for aluminum, with aluminum paint.

In some foundries, particularly those doing small bench work and using small flasks with end pouring, the flasks are set on spill troughs, which catch any spillings, or metal lost by run-outs, thus preventing much of the admixture of sand otherwise occurring.

Two firms reported good results from putting the skimmings from one melt back into the next melt of the same alloy, one firm stating that

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[a] Lewis, E. A., The selection and use of scrap: Metal Ind., vol. 10, 1912, p. 22.

[b] Krom, L. J., Fluxes from the viewpoint of a metallurgist: Metal Ind., vol. 8, 1910, p. 205.

[c] Krom, L. J., op. cit., p. 204; Sperry, E. S., Fluxes as applied to the brass foundry: Trans. Am. Brass Founders' Assn., vol. 4, 1910, p. 74.

[d] Editorial, Economics of the future: Metal Ind., vol. 10, 1912, p. 468.

[e] Editorial, The electric furnace and the scrap-metal business: Met. Chem. Eng., vol. 9, 1911, p. 621.

the gross shrinkage during a month in which this was done was 50 per cent less than in a month in which it was not done, and that although the net recovery might not be very different, it cut down the quantity of waste that had to be concentrated.

One rolling mill (Reply 151, subdivision 10 of the large table), using only a wet ball mill and no tables or jigs for recovery, reported that, by care in charging, only 0.15 per cent of the melt got into the ash, or only 0.06 per cent when their best furnace tender's work alone was considered. As not all the furnace tenders were so careful, the proportion of the gross melt recovered from ashes, spillings, etc., was 0.50 per cent. This firm skims the charcoal, salt flux, and dross into a tank of water, later drying out the charcoal and dross, riddling the material, and putting the charcoal back into the pots. The firm claims that this process effects a great saving. The loss figures are not accurately kept, and if the estimates of this firm on their loss (3 per cent gross and 2½ per cent net) are correct, their volatilization loss must be high, as the figures are rather above the rolling-mill average. A representative of the firms says that the estimate that 7,500 pounds of zinc is lost daily through the stacks of Waterbury alone [a] was high, but stated that the metal losses in the rolling-mill business were equal to more in money than the profits from the mills.

Skimming into water is generally thought to involve a saving, as it breaks up the slag and allows clean globules of metal to separate. Many plants, however, fear to do this, and in one plant a caster was killed by the explosion of a skimming tank due to the breaking of a pot in such a way that a large quantity of molten metal fell into the tank.[b] However, these tanks are usually covered, save for a small opening in which to skim, a precaution that minimizes, although it does not entirely eliminate, the danger cited.

The dropping of a little molten metal into a large volume of water is not dangerous, although the running of a large quantity of metal into a pool of water or the addition of damp metal to a pot of molten metal is. However, as accidents like the one cited are possible, skimming into water must be classed as dangerous.

RECOVERY OF ZINC OXIDE.

The recovery of zinc oxide from flue dust is often suggested. Hiorns [c] prescribes a siphon-shaped flue that carries the waste gases over running water. The water vapor is said to precipitate the zinc oxide. In literature relating to patents other forms of the same device appear as accessories to some types of furnaces.

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[a] Parsons, C. L., Notes on mineral wastes: Bull. 47, Bureau of Mines, 1912, p. 21.

[b] Editorial: Metal Ind., vol. 8, 1910, pp. 48, 172.

[c] Hiorns, A. H., Mixed metals, 1910, p. 136.

Krom [a] records that by allowing settling space in the main flue and chimney one concern recovered 80,000 pounds of salable zinc oxide. The stack was pulling on 80 pit furnaces, probably coal-fired.

One reply to the list of questions states that chimney dust is sold to the smelter, but the smelter is probably a copper smelter, the copper only being recovered from particles of brass mechanically carried along by the draft.

The recovery of zinc oxide in connection with the smelting of brass refuse has also been suggested, [b] the recovery being made along lines similar to cupola melting, the zinc fumes being run through a bag house.

Price [c] states that with coal melting, the zinc oxide is too much contaminated by dust and ashes to make its recovery feasible, but is of the opinion that the zinc oxide from furnaces fired with producer gas or oil would be pure enough to warrant recovery. Parsons [d] concludes that with gas or oil firing the recovery of zinc oxide by a proper method would be feasible.

One plant visited reported that a wet method of catching the flue dust from its oil furnaces had been tried, but that the product was not salable. However, the recovery was from an alloy containing only 15 to 20 per cent of zinc. Flue dust from yellow brass would produce a purer oxide. As Krom [e] has reported the recovery of salable oxides by the mere use of settling chambers, the application of electrostatic precipitation, such as in the Cottrell process, to brass-furnace flue dust is worth considering. Bassett [f] classes the method as a possible solution of the problem. As it works successfully on smelter fume, cement dust, smoke, etc., [g] there is no doubt but that it would effect a practically complete recovery of the zinc oxide. If no means can be found effectively to prevent the volatilization of zinc, the recovered zinc oxide might be worth enough to justify the installation of the Cottrell process in large rolling mills making yellow brass, but as zinc is worth more in the molten furnace charge than as an impure oxide, prevention is even more desirable than precipitation.

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[a] Krom, L. J., Development of melting furnaces: Metal Ind., vol. 7, 1909, p. 289.

[b] Sperry, E. S., Saving the zinc as well as copper in brass refuse: Brass World, vol. 9, 1913, p. 208.

[c] Price, W. B., Discussion in mineral wastes symposium: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 166.

[d] Parsons, C. L., loc. cit.

[e] Krom, L. J., loc. cit.

[f] Bassett, W. H., Zinc losses: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 164.

[g] Cottrell, F. G., Electrostatic precipitation of suspended particles: Jour. Ind. Eng. Chem., vol. 3, 1911, p. 542; Dust precipitation by electrostatic means: Met. Chem. Eng., vol. 10, 1912, p. 172; Mineral losses in gases and fumes: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 182; Schundt, W. A., Control of dust in Portland cement manufacture by the Cottrell precipitation process: Proc. 8th. Int. Cong. App. Chem., 1912, vol. 5, p. 117; Jour. Ind. Eng. Chem., vol. 4, 1912, p. 718; Met. Chem. Eng., vol. 10, 1912, p. 611; Bradley, L., Electrical precipitation of suspended particles by the Cottrell process: Proc. 8th Int. Cong. App. Chem., 1912, vol. 26, p. 471; Met. Chem. Eng., vol. 10, 1912, p. 686; Jour. Ind. Eng. Chem., vol. 4, 1912, p. 908; Strong, W. W., Electrical precipitation of carbon smoke: Proc. 8th Int. Cong. App. Chem., 1912, vol. 25, p. 617; Pietrusky, K., Das Cottrellsche Verfahren: Zeitschr. angew. Chem., vol. 25, 1912, p. 2107.

STANDARDIZATION OF ALLOYS.

One of the greatest wastes in the brass industry comes from using too expensive an alloy when a less expensive one would answer, or from using too cheap an alloy when the physical properties of a more expensive alloy are needed. When any nonferrous alloy is to be used for any given purpose, there are certain physical properties, such as tensile strength, ductility, frictional qualities, and resistance to corrosion, that are required. The cheapest alloys that will give these qualities with a reasonable factor of safety are the best. Too often, however, a firm buying from a jobbing foundry, or the manufacturing department of a plant ordering material from its own foundry, will specify an expensive valve metal, when all that is really needed for the work in hand is an alloy of only moderate strength with fair resistance to corrosion; that is, a yellow or red "antirust metal," as it might be called. A more rational way is to determine by experiment the physical properties that are required, and to use the cheapest composition that will meet them.

If specifications are not made, there is often a tendency on the part of the foundry to supply an alloy that is not of high enough grade to give good service in the use to which it is to be put. On the other hand, instead of finding out what properties are really required, a clerk or a foreman will decide to use on a given order some one of the regular mixtures used in the foundry concerned, without thinking whether the alloy is expensive or cheap.

The number of different alloys in the mixture book of the average jobbing foundry and, to a slightly less degree, of most manufacturing plants, is appalling, and it is a difficult task to take care of the gates and scrap from the various alloys without getting them mixed. The jobbing foundry often has to meet specifications from different customers for alloys that differ slightly, but are to be used for the same purpose, and is thus compelled to handle a much larger number of alloys than are really necessary. Moreover, when a more expensive alloy is used than is needed, the cost is high. With copper at, say 15 cents a pound, zinc and lead at approximately 5 cents a pound each, and tin at about 50 cents a pound, 0.5 per cent of copper that might as well be substituted by lead or zinc means an unnecessary cost for the alloy of 10 cents per hundredweight. If 0.5 per cent of tin could be replaced by copper, the saving would be 35 cents per hundredweight, and if by zinc or lead, 45 cents. Hence the problem is most important, and authoritative determination of the properties of alloys required for particular uses, and of the cheapest composition that will give those properties, is most desirable.

The Society of Automobile Engineers, through its standards committee, is doing a good work in drafting standard specifications for the nonferrous alloys suitable for automobile construction.

The need for such specifications is clearly shown by the various mixtures reported as used by the firms replying to the list of questions sent out. No special attempt was made to obtain figures as to the exact composition of the alloys used, the questions being designed to obtain information as to the melting practice on red brass and on yellow brass, or manganese bronze, in order that the data might be roughly separated for alloys high and low in zinc. However, in some instances the composition of a few of the alloys mostly used in the plants replying was given, although the majority of replies were on the basis of red or yellow brass. The list following has been compiled from the data furnished as to the composition of various alloys. The content of phosphorus, aluminum, or other deoxidizer has been disregarded, and the figures are accurate within 0.5 per cent.

Composition of some alloys used in brass foundries.

ALLOYS OF COPPER AND TIN.

Material.	Copper.	Tin.	Zinc.	Lead.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Bell metal	83⅓	16⅔	....	....
Do	86	14	....	....
Gear bronze	88	12	....	....
Do	89	11	....	....
Do	90	10	....	....

ALLOYS OF COPPER, ZINC, AND TIN.

Material.	Copper.	Tin.	Zinc.	Lead.
Tobin bronze	61	1	38	....
Naval brass	63	1½	35½	....
Do	73	2	25	....
Do	85	7½	7½	....
Gear bronze	86	13	1	....
Gun metal [a]	88	10	2	....
Do	90	7	3	....
Do	91	8	1	....

ALLOYS OF COPPER, TIN, AND LEAD.

Material.	Copper.	Tin.	Zinc.	Lead.
Leaded bronze, chiefly for bearings	76	9	....	15
Do	80	12	....	8
Do	80	10	....	10
Do	80½	9	....	10½
Do	82	16	....	2
Do	84	6	....	10
Do	87	11	....	2
Do	90	7	....	3

ALLOYS OF COPPER, ZINC, AND LEAD.

Material.	Copper.	Tin.	Zinc.	Lead.
Leaded brass	83	....	12½	4½
Do	80	....	18	2
Do	80	....	16	4
Do	80	....	15	5
Do	72	....	26	2
Do	70	....	26	4
Do	70	....	24	6
Cast yellow brass	67	....	30	3
Do	67	....	29	4
Do	67	....	27	6
Do	66	....	32½	1½
Do	65	....	34	1
Do	65	....	30	5
Do	64	....	32	4
Do	62	....	34	4
Do	60	....	35	5

[a] Government composition.

Composition of some alloys used in brass foundries—Continued

ALLOYS OF COPPER, ZINC, TIN, AND LEAD.

Material.	Copper.	Tin.	Zinc.	Lead.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Leaded gun metal and leaded bronze	75	9	1	15
Do	77½	6½	5½	10½
Do	80	7½	1	11½
Do	80	9	3	8
Do	81	6½	1½	11
Do	85	11	1	3
Do	87½	10	1½	1
Do	87½	10	2	½
Do	88	9	2	1
Do	88	8	3	1
Do	88½	7	2½	2
Do	90	8	1	1
Do	91	7	1	1
Do	91½	6	1½	1
Half yellow and half red metal	70	6	20	4
Do	72	6	15	7
Do	73	2	22	[illegible]
Do	73	3	21	3
Do	75	5	15	5
Do	75	10	10	5
Do	75½	1½	16	7
Do	76	1	22	1
Do	76	1	20	3
Do	76	3	18	3
Do	78½	3½	14	4
Do	78	5	16	1
Do	78	3	14	5
Do	78	3	12	7
Do	79	3	9	9
Do	80	1	17	2
Do	81	2½	16	½
Ordinary red brass or composition [a]	80	5	10	5
Do	80	6	8	6
Do	80	7	8	5
Do	80	6	7	7
Do	80	4	7	9
Do	80	9	6	5
Do	80	8	4	8
Do	81	6	8	5
Do	82	6	11	1
Do	82	6	6	6
Do	82	4	9	5
Do	82½	4	10½	3
Do	83	4	7	6
Do	83	6	6	5
Do	83½	4½	8	4
Do	84	2	8	6
Do	84	5	6	5
Do	84	4	6	6
Do	84	7	6	3
Do	84	3	10	3
Do	85	5	6	4
Do	85	6	6	3
Do	[b] 85	[b] 5	[b] 5	[b] 5
Do	85	6	5	4
Do	85	6	4	5
Do	85	6½	4½	4
Do	86	2	7	4
Do	86	5	6	3
Do	87	3½	7	2½
Do	87	2	7	4
Do	87	3½	6½	3
Do	87	5	5	3
Do	87	4½	4½	4½
Do	87½	5½	5½	1½
Do	88	2	9	1
Do	88	3	8	4
Do	88	5½	4	2½
Do	88	5	3	4
Do	89	3¾	3¾	3¾
Do	91	2½	2½	4

[a] Used for valve metals, hard brasses, steam metals, etc.
[b] One of the most common compositions.

The list does not include the various alloys of nickel, such as German silver and monel metal, nor the various types of manganese bronze. One firm sent in its mixture sheet with the request that the composition of the alloys be not published. Had these been included, 10 more would have been added to the list of alloys of copper, zinc, tin, and lead only. It is not an uncommon thing for a foundry to have from 20 to 40 different alloys of copper, zinc, tin, and lead on the list of alloys that they cast. The full list of rolling-mill alloys, none of which is included here, would also be a long one.[a]

It is, of course, conceivable that 40 alloys in a single foundry, or the list of 100 cited above in the foundry industry, is warranted, and that each has its particular use. However, it is certain that each of the nine different compositions of cast yellow brass shown in the table can not be the cheapest that would serve for the use to which such brass is put. It is also certain that, even if the value of the scrap of the more expensive alloys is as much more than that of the cheaper alloys as the composition would indicate, a doubtful relation judging from the usual methods of sale and use of scrap, some firms are unnecessarily tying up good money in the extra cost of a more expensive alloy than is needed.

Another cause of waste is the weighing of small quantities of expensive metals, such as tin, on large scales not sufficiently delicate for the purpose, a method by which it is easy to add to a small pot of metal a half or a quarter of a pound more of tin than is required by the formula. On the other hand, too little tin may be added to give the desired properties. Small, accurate scales only should be used for weighing small quantities of metal. One foundry visited uses a decimal system in all its weighing. The pound is still the unit, but the scales read in pounds and tenths of a pound, the word "ounce" not being used in the foundry. This arrangement means a great deal less work in calculating furnace charges.

The metallurgist of one rolling mill called attention to the waste occasioned in the remelting, in rolling mills, of copper for casting rolling ingots, as many of the standard sizes of ingots might as well be cast direct from the refining furnace in the smelter and sold to the rolling mills ready to be rolled instead of in ordinary ingot form.

EMPLOYMENT OF A METALLURGIST.

The best way to make sure that the proper alloy is chosen for a particular purpose, and after the composition of the alloy has been selected, that the proportions of the components are maintained within working limits, is to have a competent metallurgical chemist or metal-

[a] See editorial, Economies of the future: Metal Ind., vol. 10, 1912, p. 468; Krom, L. J., Manufacture of wrought brass: Metal Ind., vol. 8, 1910, p. 8.

lurgical engineer, whose business it is to fit an alloy to the desired properties in the cheapest way, to vary the alloy to get a cheaper alloy with the same properties as the metal market changes, to make up the mixtures in accordance with the quantity and the analysis of the scrap that is to be used, and to supervise the melting process as well. Also under the supervision of a metallurgist come the examination of such material as new metals, scrap metals, composition ingot, molding sand, core sand, core binders, fluxes, fuels of all sorts, etc., which should either be bought under specifications or analyzed or tested for their suitability for foundry use; physical testing of the alloys produced; efficiency tests of furnaces and methods of furnace operation; control of metal mixtures, furnace operation, core mixtures, core-oven operation, and core testing; determination of the proper baking temperatures for cores; and operation of the ovens under pyrometric control.

If no metallurgist is employed, it is a step in advance to have an analyst to determine the composition of such alloys as may be submitted to him, but to obtain the fullest benefit from chemical work there should be chemical control of the mixtures as well. A mere analyst who is not able or not allowed to control the mixtures and the melting can not help his firm to anything like the degree that a metallurgist, using his chemical knowledge in supervision of the melting room, can. As Bragg[a] puts it, "the laboratory with a 'chemist' is not worth nearly so much as a chemical engineer who has a laboratory."

The metallurgist is usually the best man to maintain, as well as to establish, on the basis of his tests, the standards for melting speed, fuel consumption, and metal loss in the furnaces used, and he is the best fitted one for finding out and eliminating the causes of foundry and mill defects in the metal. Metallurgists are not only becoming more common in brass foundries and rolling mills, but, in plants where their activities were formerly confined solely to the laboratory, are being given fuller charge of the practical matters with which they are especially fitted to deal. It is almost as common to see advertisements stating that the nonferrous alloys produced by the advertiser are made under the control of skilled metallurgists as it is to see a similar statement of chemical control in the advertisements of automobile tires.

Primrose[b] reflects the English attitude in the paragraphs following:

For the accurate control of a brass foundry, it is essential to have a well-equipped metallurgical and testing department, especially when the products have to conform closely to specification. Accurate knowledge of the allowances to be made in melting must be ascertained, and the amount of oxidation and volatilization losses under the particular conditions of working must be determined in order to maintain a uniform

[a] Bragg, C. T., The chemical engineer in the brass foundry: Metal Ind., vol. 8, 1910, p. 64.
[b] Primrose, H. S., A discussion of modern brass founding: Foundry, vol. 40, 1912, p. 366.

composition of the resulting alloys. All scrap metal bought should be melted, cast into ingot, and stacked in lots according to its analyses. The best results are obtainable only by making up the proportions of the charge constituent from the laboratory analysis, and in order to keep a thorough check on the resulting melts it is advisable to have these analyzed also. All raw material, such as copper, tin, zinc, scrap, etc., should be bought to analysis and carefully checked on delivery to insure that it conforms to specification. Where it is not possible to purchase on this basis the material ought to be carefully analyzed, and mixed accordingly.

The cost price of an alloy is largely determined by the price of the component parts, and when these differ considerably in value, even a slight variation in the alloy composition increases its cost. A wide variation may quite easily occur in practice which is not controlled by chemical analysis, so that the cost of chemical control soon pays for itself several times over.

It is well known that the German attitude is similar.

The coming American attitude is reflected by a recent editorial [a] which says:

The continual advance of metallurgical knowledge will lead in the near future to a complete change in the method of brass manufacture. * * * Works which are now employing their own chemists, and by chemist we mean a professional man, not a rule-of-thumb tester, find that they can not do without him and he is becoming more and more useful in the foundry and rolling mill. The sneers of a few years ago, when so-called practical men laughed at the idea of a chemist in a brass mill or foundry, are things of the past. It is a wonder that the trade has existed so long without a chemist. It is a sign of progress when firms advertise for a metallurgist to take charge not only of their laboratory but also their foundry.

Sperry [b] says:

To-day, the chemist is as much a need in the brass business as the actual casters or melters themselves, and his employment has changed the industry from one of the "rule of thumb" to one conducted upon a scientific basis.

APPLYING SCIENTIFIC MANAGEMENT TO FURNACE PRACTICE.

The brass-foundry and rolling-mill industry is taking a great interest in the recent industrial development known as scientific management, as is evidenced by the fact that both the American Institute of Metals and the American Foundrymen's Association had papers on the subject at their joint meeting in 1913.[c]

Although the books and papers of the leaders of the movement deal mostly with efficiency in its larger application to industry in general,[d] to some specific industry as machine-shop practice,[e] or

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[a] Economies of the future: Metal Ind., vol. 10, 1912, p. 467.

[b] Sperry, E. S., What the chemist has done for the brass industry: Brass world, vol. 9, 1913, p. 343.

[c] The titles of the papers before the American Institute of Metals were as follows: The efficiency engineer in the foundry, by E. A. Barnes; How scientific management worked in our plant, by C. B. Bohn; Preparation for scientific management in our plant, by W. M. Corse; Core room economies, by O. F. Flumerfelt. The titles of the papers before the American Foundrymen's Association were as follows: How to make a time study (also read before the Am. Inst. Met.), by C. E. Knoeppel; Put your house in order, by F. A. Parkhurst. These papers will appear in the 1913 transactions of the two societies.

[d] Taylor, F. W., Shop management: Trans. Am. Soc. Mech. Eng., vol. 24, 1903, p. 1; The principles of scientific management, 1911; Emerson, H., Efficiency as a basis for operation and wages, 1912; Twelve principles of efficiency, 1912; Gantt, H. L., Work, wages, and profits, 1911.

[e] Parkhurst, F. A., Applied methods of scientific management, 1912; Gilbreth, F. B., Concrete system, 1908; Brick-laying system, 1909.

to foundries in a general way,[a] there is no published account dealing in any detail with its application to brass-furnace practice.

As all authorities on scientific management, although differing in detail, agree on certain principles of operation of any industrial plant, and as those principles, as indicated by a study of the furnace data collected in this investigation, may profitably be applied to furnace operation for the elimination of waste, it is easiest to sum up the basic principles of the proper operation of brass furnaces by using some of the phraseology of scientific management.

The use of the term "management" as applied to the operation of brass furnaces gives the correct point of view in two ways—it serves to emphasize the fact that the operation of a furnace is as important as the type of furnace designed or the fuel used, and it places the responsibility for preventable waste on the shoulders of the management, instead of on an inanimate furnace, or a possibly illiterate furnace tender.

Under any form of management that may fairly be called scientific, some of the vital details are: Proper choice of equipment; standards based on actual scientific tests; maintenance of standards; and accurate and adequate records as a means of maintaining standards.

PROPER CHOICE OF FURNACES.

In choosing a brass furnace, the selection should be made with reference to the alloys to be melted, their liability to volatilize, the quality of metal desired as regards freedom from oxidation and gas absorption, the quantity of molten metal to be produced, and the cost of the various possible fuels in a given locality. For some alloys, the whole range of furnace types might give the quality of metal desired, but certain types of furnaces might be barred by their lack of speed, and other types by the cost of fuel. For other alloys, the volatility of zinc might eliminate some furnace types; or the necessity for large production might be absent, so that a relatively slow furnace would serve, and the fuel cost might then be the deciding factor. There is no one best brass furnace, but for any specific purpose and locality there are types that are more efficient and those that are less so. Elimination of unfit types for the purpose in hand may better be effected by considering, first, the quality and quantity of molten metal they should produce, and, second, their fuel efficiency, first cost, and upkeep charges.

ESTABLISHMENT OF STANDARDS OF FURNACE OPERATION.

After the furnaces have been selected, standard conditions for their operation should be designated and maintained. Such a standard involves seeing that the fuel supply is of the proper grade,

[a] Knoeppel, C. E., Maximum production in shop and foundry, 1911.

that blowers, oil pumps, and all other appurtenances of the furnace selected are kept in proper condition. The metallurgist should make tests of his furnaces to determine the melting speed of which they are capable, the maximum fuel efficiency, and the minimum melting loss that they can give, with proper operation, on the alloy used, and should designate the results as the standards. He should then train his furnace tenders so that the daily operation of the furnaces meets the standards.

To get the highest efficiency from any type of furnace, it should be run at its maximum speed; that is, the metal must be poured and a new charge put in the furnace just as soon as the metal reaches the proper pouring temperature. This practice gives the greatest production, the highest fuel efficiency, the lowest metal loss, and the least gas absorption. Fewer furnaces run at full speed will be more economical than a larger number run at less than their limit of speed. "Soaking" the metal is bad from every point of view. Holding the metal in the furnace while waiting for the molds involves "soaking." The less "fool proof" the furnace, the worse the result of holding the metal. A case in point is cited by Dean.[a] In a coal-fired, reverberatory furnace, melting manganese bronze, when the melt is waiting for the mold, an addition of 2 or 3 pounds of zinc per hundredweight of the metal is necessary to keep the alloy at the desired composition.

In order to have the molds ready when the metal is ready, the supply of molten metal and the production of the molds must be properly balanced. This relation involves producing both at a known rate, and necessitates previous planning so as to have both ready simultaneously. The foundryman can easily see that his management is not scientific when the molders are idle because all the flasks for a given job are ready to be poured and the metal is not ready. He is not so likely to realize that losses of fuel, of metal, and of quality of metal are also going on when the metal is waiting for the mold. Perfection can not always be reached, and it may be less costly to "soak" the metal than to have the molder idle, but if such a case now and then occurs, the manager should realize that he is putting his furnaces at a disadvantage, and that the high fuel consumption, the high metal losses, and the bad castings from the gas in the metal are due, not to anything inherent in the furnaces, but to his failure to operate them on a proper schedule.

That there is, in ordinary practice, or even in practice better than the ordinary, a considerable discrepancy between fuel consumption and metal losses on a test and in regular practice is easy to demonstrate. In this connection, figures are given by Hansen[b] on two

[a] Dean, W. R., Foundry tests and foundry practice: Trans. Am. Inst. Metals, 1912; Metal Ind., vol. 10, 1912, p. 449.

[b] Hansen, C. A., Electric melting of copper and brass: Trans. Am. Inst. Metals, 1912, advance copy, p. 6.

makes of open-flame oil furnaces, melting an alloy containing about 16 per cent of zinc. Furnace A, under test, used 2.02 gallons of oil per hundredweight of metal melted, the metal lost being 2.28 per cent. Under operating conditions, furnace A used 3.46 gallons of oil per hundredweight, 5.82 per cent of metal being lost. Furnace B, under test, used 1.78 gallons of oil per hundredweight, 1.81 per cent of metal being lost, whereas, under operating conditions, it used 1.97 gallons of oil per hundredweight, the metal lost being 2.50 per cent.

Another illustration is furnished by the special test described under Reply 16. In that test the gross melting loss in melting red brass in four forms of oil furnaces and in a coke furnace ran between 0.63 and 0.88 per cent, whereas the gross loss in ordinary practice is given as 3 per cent.[a]

The low loss on gun metal in the special test described in Reply 79, covering three different types of furnaces that gave gross losses of 0.42 to 0.54 per cent, might be compared with ordinary practice. Reply 19 describes tests in which the losses were 2.25 and 2.43 per cent, whereas the figures for regular practice are 5.4 per cent gross and 4.4 per cent net.

The recovery of metal from ashes and spillings represents metal that, with the same care in regular operation that is taken in tests, would have gone where it was desired and would not have had to be recovered, to say nothing of what was lost and not recovered.

There is, of course, a point at which care costs more than the fuel or metal lost, but the foundry or mill that has reached this point is remarkable. The figures for fuel consumption and metal losses shown in painstaking tests, and, in many cases, by the catalogues of furnace makers, can not always be economically reached in the hustle of every-day production, yet they form a standard, and the manager should know how far away from that standard his daily work is, and whether it is cheaper to allow the discrepancy or to correct it.

FOUNDRY RECORDS OF FURNACE OPERATIONS.

In order to maintain the standards of speed, fuel consumption, and metal losses that have been established, a prompt and accurate record of the performance of the furnaces is essential. Some few plants, notably some rolling mills, keep a daily record of the performance of the furnaces run by each caster. The record covers the production, the metal lost, the recovery from the ash, the fuel consumption, and the amount of metal produced that is defective through improper melting. The records may form the basis for an efficiency reward or system of bonus pay for work done according to instructions. They at least allow the manager to know at all times whether

[a] See subdivision 1 of the large table.

the production of his furnaces is reaching the standard, and if not, to find out the cause and remedy it at once. Contrast this facility with the conditions in so many plants where coal or coke is never weighed for the furnace charges, oil furnaces are not metered, and no idea at all can be formed of the melting losses. The mechanical equipment of many plants is admirable and the quality of work high, and yet the operation of the furnaces may be utterly extravagant in fuel and metal losses. If the same care and thought were put on the elimination of these losses that has been given by the management to other parts of the plant, the losses would be vastly reduced.

The calculation of fuel consumption and metal losses figured from a yearly or even monthly inventory is of little or no aid in furnace control. In order to detect waste in furnace operation, the figures must be available at the exact time that the wasteful condition occurs, and must promptly reflect increased or decreased efficiency, a result that involves the daily or, at the least, the weekly summation of the furnace records. Several of the plants visited or replying to the questions had proper records, and more were just starting to attain them, but the total number of plants that keep records of any adequacy is exceedingly small. Of the 1,650 plants receiving the list of questions, only 230 replied with any data, and about 50 stated that no records at all were kept. It is a fair inference that few of the 1,420 that did not supply data keep adequate records. Of the 230 that did reply, about 30 keep records sufficient to keep the management continually informed of the efficiency of the furnaces and the metal loss, some 40 have records that would be more or less useful, and 10 have made furnace tests but have no regular records. The other 150 either state explicitly that they keep no records on the details mentioned above, or that the figures reported are only estimates, or else, in about 30 cases, the figures are seemingly derived from an inventory, taken in such a way as to give no real accuracy. To the inaccuracy of the estimates are due a great many of the inconsistencies in the different replies to the list of questions.

It is doubtful whether there are 50 firms in the country that know how their furnaces are running with sufficient exactness from day to day to allow the correction of avoidable wastes. The firms that have such knowledge almost invariably have a metallurgist who has supervision of the melting room, and almost always have the lowest losses.

Although more and more firms, particularly the largest ones, are dropping into the line of progress, the great majority still run their melting rooms without records, and in the way so vividly described by Redfield,[a] in a chapter on "The Days of the Rule of Thumb."

[a] Redfield, W. C., The new industrial day, 1912, pp. 18–40.

SUGGESTIONS FOR FURNACE TESTS AND RECORDS.

No general rules for making tests of furnaces or for keeping furnace records, nor, still less, any set forms, can be laid down that will be applicable to the varied conditions in all plants melting brass. A few details that should be kept in mind in planning either furnace tests or a system of daily records, and some of the variables in regard to the nature of the castings made that must be considered in comparing results from various foundries may, however, be briefly outlined.[a] The data should cover the variables involved in determining the suitability of the furnace for the particular conditions of the user, fuel cost, attendance cost, crucible cost, speed of melting, oxidation and volatilization losses, and quality of metal produced, and should contain answers to the following questions:

Questions that should be answerable from records of furnace tests or operations.

NATURE OF WORK AND SPECIAL CONDITIONS.

1. Is the plant a rolling mill casting ingot only; a part of a manufacturing plant, making large numbers of similar castings; or a jobbing foundry with a varied run of work?

2. Nature of castings (as plumbing goods, auto parts, etc.); bench or floor work; heavy or light; average weight per casting; ratio of weight of gates and sprues to castings.

3. Is work so light as to require very hot metal? Average temperature in furnace? Average pouring temperatures?

4. After the metal is hot enough to be poured, is it usually held in the furnace to await the preparation of molds? Could you get more heats per day from one furnace if you could use the metal, or are all furnaces running used to fullest capacity?

5. Which of the factors mentioned below chiefly influenced you in your choice of a furnace for your work:

(*a*) First cost of furnace and equipment.
(*b*) Cost of upkeep.
(*c*) Cost of attendance.
(*d*) Cost of crucibles.
(*e*) Cost of fuel.
(*f*) Oxidation and volatilization losses.
(*g*) Quality of metal produced.
(*h*) Speed of melting.
(*i*) Convenience and sanitary conditions.

FURNACE CONSTRUCTION.

6. *Type of furnace.*—Coal or coke, gas, oil, or electric; pit or tilting; crucible stationary or removed to pour; natural or forced draft (in ounces or pounds per square inch); stack dimensions; number of furnaces; size of combustion chamber; height of crucible blocks; power used in blower; compressor or oil pump serving furnaces; pressure of oil or gas and of air at burner; oxidizing or reducing flame.

7. *Fuel.*—If coal and coke, analysis and British thermal units per pound; if gas, British thermal units per cubic foot; if oil, specific gravity (state at what temperature) and British thermal units per pound.

8. Size and shape of crucible or melting chamber; material; capacity per charge (state in pounds of metal).

[a] See Gillett, H. W., Letter from committee on cooperation with the Bureau of Mines: Am. Inst. Metals Bull. 19, Dec., 1912, p. 17.

SPECIFIC INFORMATION FOR EACH TYPE OF FURNACE.

9. Duration of test reported.

10. Total pounds of metal melted in period; pounds of new metal (state whether ingot, wire, or punchings); pounds of alloyed metal (state whether gates, sprues, or large scrap); pounds of alloyed turnings.

11. Gross loss, including metal recovered; net loss; net percentage of oxidation and volatilization loss, corrected. Does this include grinding losses?

12. Quantity of fuel used per hundredweight of metal melted.

13. Crucible life in number of heats per crucible and in crucible cost per hundredweight of metal melted.

14. Character and extent of furnace repairs, linings, etc., during period.

15. Number of furnaces per furnace tender.

16. Number of pounds of metal melted per furnace tender per hour.

17. Average time required to melt 1 hundredweight of metal per furnace.

18. Composition and tonnage of the different alloys melted in the period.

19. Discussion of quality of metal melted in different batteries under test.

To get the information outlined above, separate records are necessary for each battery of different types of furnaces in foundries using more than one type. Furnace results should not be lumped from two or more of the following types: Coke, pit; coke, tilting; oil or gas, with flame impinging on metal; oil or gas with crucible stationary; oil or gas with crucible pulled to pour. For obtaining records as to fuel consumption, coal or coke may be weighed into bins and used only for melting during the period of a test; oil or gas should be metered and none taken in front of the meter for other purposes. Fuel used to preheat pouring crucibles or ladles should go in with that used for actual melting, as it is a charge against the type of furnace that requires pouring crucibles or ladles. Power used in producing air blast or oil pressure for furnaces should be charged against the melting cost.

Records of crucible life and furnace repairs are most easily kept by the head furnace tender. Pouring crucibles or ladles used up in the test period are a charge against tilting furnaces. Attendance costs are best kept by the accounting department, which should know daily the number of furnaces going in each battery, the number of furnace tenders employed, the hours worked by each, and the number of heats per day, as well as the quantity of metal melted. The four great items are fuel cost, labor cost, crucible cost, and "shrinkage," or metal lost by oxidation and volatilization. Records of the first three are more easily kept than of the last. The actual melting loss in furnaces only is hard to get under foundry conditions. If a crucible of metal is poured into many small molds, the oxidation and volatilization during pouring is greater than if poured into a single large mold. Loss on remelting grindings is greater on small castings with many gates and sprues. These losses are chargeable to the patterns used and not to the furnaces. One way to get melting losses only is to weigh pouring crucibles or ladles plus molten metal

and to allow tare for the empty ladles or crucibles; or the castings may be weighed at the grinding room, the weight of the attached gates and sprues being included, but the core and molding sand being knocked off; proper credit should be given for both good and defective castings and for any skulls or metal poured into ingot instead of into castings. In this case the furnaces should not be credited with grindings recovered, or with anything else recovered except the skimmings, spillings, etc., obtained in the melting room and in the molding room.

A less satisfactory but more common way is to include the grinding losses and to credit the furnaces with the weight of the good castings, the defective castings, the gates and sprues, and all metal recovered from skimmings, spillings, and grindings, the weighing being done after the castings have passed the grinding room.

In any case it is essential that the furnaces be debited with all new metals, composition ingot, gates, sprues, or large scrap, and borings or grindings received daily from the metal stock room, being credited with any such metal returned unmelted, and with the total castings, gates and sprues produced, as well as with the metal recovered by the recovery department (less the cost of recovery, which can be figured into equivalent pounds of metal). The value of any tailings, etc., sold can be converted into equivalant pounds of metal and credited to the furnaces.[a]

In order to obtain figures on true melting loss, it is imperative that the remelt of gates, sprues, and defective castings be not neglected. Such a record involves having a metal stock room to which all gates, etc., go, and from which they are charged out to the furnaces, rather than having the gates brought back to the furnace and remelted without any record. Usually the best method is to make up the furnace charges in the metal stock room, each separate charge being sent to the furnace in a tray or tote box. In some plants the weighing is semiautomatic, and the charges are mechanically conveyed to the furnaces.[b]

When prompt and accurate records are obtained, the next thing for the management to do is to utilize them. A prescription is of no value unless it is taken, and unless the manager takes steps to remedy wrong conditions when his furnace records or graphic charts show that they exist, he might as well not have them.

[a] See Olsen, L. W., A system of distributing waste losses in raw material to the cost of finished products: Trans. Am. Brass Founders' Assn., vol. 3, 1909, p. 9.

[b] Thompson, G., A model metal-casting shop of the Naugatuck Valley: Metal Ind., vol. 11, 1913, p. 207.

CAUSES OF DISEASE AND DANGER AND ESSENTIALS FOR HEALTH AND SAFETY.

One of the most important essentials is that proper attention be given to conserving the health and promoting the safety of employees. In this connection Dresser [a] says:

> On the whole, the movement in behalf of efficiency means an intelligent effort to provide for individual work under conditions more favorable for all concerned. It therefore becomes a matter of scientific necessity to provide for the welfare of each employee. When it is a question of the best work each can do, work that is performed in the best manner, attention must be given to any number of conditions that would otherwise be neglected. Accordingly more heed is paid to sanitary conditions, to the number of hours, and the conditions under which each employee can work to greatest advantage.

The problems of furnace design, construction, and operation in their effect on the waste of metal and fuel are receiving attention in up-to-date foundries and mills. Those of the effect of the construction and operation of plant and equipment on the waste of the workmen's health and of their lives are also being earnestly studied by the brass industry. Plants whose motto is "Safety first and profits second" are no longer rarities. Much, however, remains to be done.

Brass founding is commonly regarded as an unhealthful occupation, although the operations that comprise the bulk of the work in molding and core making do not in themselves involve anything that can be classed as unhealthful. The unhealthful part of the brass-foundry business comes from excessive heat, smoke, dust, or fumes incident to melting the metal, to pouring it into the molds, knocking the cores from the castings, sawing off gates, grinding castings, sand blasting, etc. Each of these operations can readily be so safeguarded as to be without injurious effect on the health of the workers.

The bad reputation of the brass foundry in regard to health is due more to the construction of the older foundry buildings than to anything inherent in the trade.

Most industries that deal chiefly with hand labor show a slower improvement in housing and in general working conditions than those requiring high-grade machinery. Also, industries that require little equipment and few workers are slower in showing improvement on lines of health and safety than those that naturally tend to centralization and the employment of large numbers of workers. Brass foundries, even to-day, have little machinery in comparison with that used in most industries, and the machinery is of heavy type. Up to recent years foundries have been of rather small size, with few workers. The foundries doing purely jobbing work as a class are distinctly behind the foundries run as an adjunct to large

[a] Dresser, H. W., Human efficiency, 1912, p. 3.

manufacturing plants. In such plants the construction of modern shops and a large total number of workers have brought their foundry departments to an advanced point in surroundings and sanitation that the jobbing shops as a class have yet to reach.

The words "brass foundry" used to bring up a mental picture of a low wooden shack, poorly arranged, with perhaps a number of sheds or small rooms that were added to the original building as the business expanded (a condition so common that such additions has gained the name of "dog house"). The buildings were poorly lighted, poorly ventilated, often not heated at all except by the melting furnaces, cold in winter, hot in summer, always full of smoke and fume, grimy with the accumulated dust of scores of years, and with toilet and lavatory facilities of the crudest sort.

This picture is rapidly giving way to one of a high, light, airy structure to which a superintendent need not be ashamed to take a visitor after showing him through a modern machine shop. Dirt there is, and must be, nor will the stage be reached where white-flannel trousers and white collars are suitable attire for the foundryman at his work, but there is little excuse for dirt of a nature that will be harmful to health.

"BRASS SHAKES."

The main reason why the brass industry is classed as unhealthful is found in the occupational disease known as "brass-founder's ague," or, more commonly, "brass shakes," or "spelter chills."

The symptoms [a] of "brass shakes" are a dry throat, a general feeling of lassitude, a hacking cough, a dull headache, a feeling of oppression in the chest, difficulty of thoracic breathing, and sometimes a feeling of nausea. In a few hours, but usually not until the subject leaves the furnaces in the evening, so that perspiration ceases, a slightly chilly feeling occurs, which increases to a distinct rigor, the subject shaking violently. During the chill, the actual temperature may rise to as high as 103° F. The chill is accompanied by muscular pains. After a few hours the chills cease rather suddenly and a profuse perspiration sets in. The attack is then over and the patient sleeps profoundly, rising in the morning with only a slight feeling of weakness. Zinc is eliminated in the urine and feces, and its presence is suspected in the perspiration also. Swelling of the spleen and albumen in the urine are also sometimes reported.

The disease is somewhat similar to malarial ague. There is no specific remedy. The chilly feeling creates a desire for warming drinks, and the workmen commonly drink alcoholic stimulants to satisfy this desire. Alcohol, however, is not only not a remedy but

[a] Compare Sperry, E. S., Spelter chills: Brass World, vol. 7, 1911, p. 40.

makes the worker far more susceptible to the attacks. This result is indicated by a dozen replies to the list of questions issued in this investigation, and is so well recognized that the disease is often termed "whisky shakes" or "booze shakes." Although abstainers and moderate drinkers may have the "shakes," the ailment is far more common among heavy drinkers. Hot milk, milk and eggs, and milk and pepper, taken in large quantities, and the use of a mild purgative shorten the attack and decrease its severity, the zinc probably being precipitated as an insoluble albuminate. This treatment may also ward off an attack.

The theories as to the exact agent that causes the disease are varied, the blame being variously laid on zinc oxide, metallic zinc, arsenic, cadmium, copper, a mixture of copper and zinc, or carbon monoxide, and Hayhurst [a] suggests zinc carbonyl.

Of these the most probable cause is zinc oxide,[b] the main constituent of the fumes. It is unlikely that metallic zinc reaches the lungs unoxidized. No definite proof has been adduced to show that the minute traces of arsenic that may be present as an impurity are the cause. Cadmium is far more volatile than zinc, practically all the cadmium in the spelter being lost.[c]

Copper fumes may cause poisoning,[d] but no copper is volatilized by the ordinary temperatures of brass melting, though traces may be mechanically carried by the zinc oxide. Hansen does not mention chills in his account of copper poisoning. However, the symptoms of poisoning by copper fume and those of poisoning from mercury vapor both have some resemblance to those of "brass shakes," Kisskalt [e] finding that the symptoms of poisoning by the inhalation of various metal vapors were more similar than when the metals were absorbed through other causes.

Carbon monoxide headaches are reported in some plants where oil furnaces are installed without any attempt at hooding, but the symptoms are quite distinct. Moreover, Siegel [f] has shown the absence of carbon monoxide hemoglobin in the blood of patients suffering from the "shakes."

Zinc carbonyl deserves no serious consideration for, as Mond [g] states, the carbonyls of nickel and iron are the only ones that can be

[a] Hayhurst, E. H., Occupational brass poisoning—brass-founders' ague: Am. Jour. Med. Sci., vol. 145, 1913, p. 752.

[b] Rambousek, J., Gewerbliche Vergiftungen, 1911, p. 196.

[c] Bassett, W. H., Zinc losses: Jour. Ind. Eng. Chem., vol. 4, 1912, p. 164.

[d] Hansen, C. A., Copper poisoning: Met. Chem. Eng., vol. 9, 1911, p. 67; Jour. Inst. Metals, vol. 5, 1911, p. 304.

[e] Kisskalt, Über das Giessfieber und verwandte gewerbliche Metalldampfinhalationkrankheiten: Zeitschr. Hyg. und Infectionkrank, vol. 71, 1912, p. 472.

[f] Siegel, J., Das Giessfieber: Vrtjschr. gerichtl. Med., vol. 32, 1906, p. 174.

[g] Mond, L., Note on the volatilization of heavy metals by means of carbon monoxide: Trans. 7th Int. Cong. App. Chem., sec. 2, 1910, p. 8.

formed at atmospheric pressure, cobalt carbonyl requiring 100 atmospheres and molybdenum and ruthenium carbonyls 450 atmospheres; no others are known.

The fumes from the purest zinc are known to give rise to attacks of "spelter chills" exactly the same as "brass shakes" are known in zinc smelters. It has been thought that zinc was not the cause because hot galvanizers and workers in almost pure zinc castings do not have the "shakes." Reference to figure 2 will indicate that the reason for this is simply that the working temperatures represented are below the point at which pure zinc is appreciably volatile.

Some persons, especially those not indulging in alcohol liquors, are naturally immune from the "shakes." Most others, if constantly breathing small amounts of zinc fumes, develop practical immunity, and have the "shakes" only when they get an overdose of fume, as when ventilation is poor, or after a day of rest, when the system becomes freer from zinc. Monday night is the time when most cases of "shakes" occur, both because the system rids itself of some zinc over Sunday, and in some cases, because the Saturday night and Sunday indulgence in alcohol puts the system in such condition that the subject is more susceptible. Most rolling mills have trouble from "shakes" when cold weather sets in and ventilation is reduced.

A few workers do not develop much of any immunity and have to abandon working amid zinc fumes, but such cases are rare. As a certain natural immunity exists, one method of cutting down the number of foundry workers attacked by "shakes" suggests itself. Instead of having each molder pour his own molds, the pouring may be done by a pouring gang whose task is pouring only, an arrangement that also has advantages as regards production. If the pouring gang is composed of immunes, and the molders keep out of the fume while their molds are being poured, fewer cases of "shakes" would be expected.

The "shakes" are inconvenient and unpleasant, but seldom or never fatal, very few cases ever coming under the hands of a doctor. The ailment may, however, cut down the efficiency of the worker, and its occurrence in a shop is an indication of conditions that can not promote the physical good of any of the employees, even those not appreciably affected.

Whether it actually does permanent physical harm is a subject for controversy.[a] Everyone grants that it involves temporary discomfort, and some writers claim that it lowers the bodily resistance, so that other ailments, particularly pulmonary diseases, are more readily contracted, and that the average life of brass melters and casters is thereby reduced.

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[a] Jones, J. L., Zinc poisoning: Metal Ind., vol. 11, 1913, p. 42.

Rambousek[a] states that casters who have had repeated attacks of the "shakes" may become emaciated and may contract digestive disorders and catarrah of the respiratory organs as a result of chronic zinc poisoning.

He further states that attacks are likely to bring palpitation of the heart or asthma. If asthma be considered synonymous with mere shortness of breath, the statement is doubtless true. However, the author, though subject to attacks of true asthma since childhood, and though extremely sensitive to some of the exciting causes of hay fever, particularly the odor of a sweaty horse, has never developed an attack of asthma from exposure to zinc fumes, notwithstanding the fact that on a number of occasions such exposure has brought on all the ordinary preliminary symptoms of "brass shakes" save that of nausea, the "shake" ending in distinct chills, though seldom of such severity as to cause actual shaking.

Hoffman[b] gives the normal male mortality from consumption as 14.8 per cent, and states that the mortality from consumption among brass workers is 38.9 per cent. His figures for brass workers include workers who grind castings as well as those who melt and cast metal. As he gives the percentage of mortality from consumption for grinders alone[c] as 49.2, the figure for deaths from consumption among brass melters and casters would be less than 38.9 per cent. Statistics cited by Hoffman for England and Wales during 1900 to 1902 show a slightly higher mortality among brass workers than the normal figure for occupied males, but the figures are not in sufficient detail as to the various branches of brass working to throw much light on the effect of "brass shakes."

Oliver[d] states that out of 1,200 casters in Birmingham only 10 were more than 60 years of age.

Krom[e] admits that pneumonia and consumption are common.

Hayhurst[f] finds only young men in the brass foundries of Chicago, and claims that iron founders as a class are older than brass founders.

Hayhurst[g] also makes the following statement:

A single attack of brass chills is in itself not dangerous, and as they come on usually at night time the workmen rarely lose any time from work, at most not more than the day following the chill. Once back and at work they become rapidly inured and no longer subject to the chills. But the constant repetition of these chills, or the constant exposure to the conditions producing them, ultimately ends in chronic diseases, usually affecting the lungs, digestive tract, nervous system, and kidneys.

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[a] Rambousek, J., Gewerbliche Vergiftungen, 1911, p. 233.

[b] Hoffman, F. L., Mortality from consumption in dusty trades: Bull. U. S. Bureau of Labor, No. 79, 1908, p. 667.

[c] Hoffman, F. L., op. cit., p. 649.

[d] Oliver, T., Dangerous trades, 1902, p. 461.

[e] Krom, L. J., Dangers of the casting shop: Metal Ind., vol. 8, 1910, p. 172.

[f] Hayhurst, E. H., Occupational brass poisoning—brass-founder's ague: Amer. Jour. Med. Sci., vol. 114, 1913, p. 728.

[g] Hayhurst, E. H., Report of Illinois Commission on Occupational Diseases, 1911, p. 56.

Following the publication of the report of the Illinois Commission on Occupational Diseases, there were a number of articles in the popular magazines in which lead poisoning, phosphorus poisoning, and "brass shakes" were treated together, and the general impression was given to the public that all three occupational diseases were in the same class. This classification has been resented by many of the representative men of the brass rolling mills of Connecticut, who expressed themselves strongly on the subject when their plants were visited. One superintendent stated that "brass chills" had no more permanent harmful effect on the human organism than seasickness, and that as his casters averaged only one slight attack of "shakes" per year—at the beginning of cold weather—he objected to having the public misled into considering that the conditions in his mill were on a par, in regard to dangerous occupational diseases, with those in the white-lead industry and the match industry of former days.

Some of these men were inclined to discredit the investigations of medical men who had made errors in their statements in regard to brass furnaces and alloys, such as, for instance, the statement that the cupola furnace was the preferable type, or that copper boils at 1,300° C., both of which are highly incorrect. Thus the rolling-mill men may not have given due weight to the medical facts on which these writers can speak with authority.

It must be admitted, however, that in the Naugatuck Valley of Connecticut where more alloys high in zinc are melted than in all the rest of the country combined, and where the true facts as to the danger or harmlessness of "brass shakes" should be best known, neither the management nor the casters themselves consider "brass shakes" permanently harmful. Bassett[a] says:

> The effect of the zinc fumes on the health of the casters, in the ordinary casting shops, at least those connected with the wrought-brass industry, are not any more harmful to health than is the use of tobacco. Throughout the large mills of Connecticut you will find as fine-looking men engaged in casting brass as you can find in any trade where the work is carried on in intense heat. They are mostly big, husky men who enjoy life to a good old age, and do not seem to mind the effect of the zinc. Occasionally there are men who do not seem able to stand the work, the same as in any trade where work is severe and hot, but in almost every instance the casters of brass are healthy and apparently not injured in any way by the zinc fumes which, to people who are not accustomed to them, are quite troublesome.

The casters merely laugh when "brass shakes" are mentioned and do not seem to fear them in the least, as it is extremely rare for an attack to be so severe as to involve absence from work and loss of pay.

The attitude of the managers may be biased, and that of the casters may be due to too great familiarity with the disease to give it its true significance. The writer talked with a number of chemists and metallurgists of the Connecticut and other rolling mills. These men

[a] Bassett, W. H. (In discussion): Jour. Ind. Eng. Chem., vol. 4, 1912, p. 167.

have almost all had considerable experience with "brass shakes," as their work takes them intermittently to the casting shop where they inhale enough zinc fumes to give them the "shakes," but seldom enough to develop the immunity enjoyed by the casters. They are far enough from either the managerial or the workman's point of view, it would seem, to form an impartial opinion. Their opinion is that, although the "shakes" are unpleasant, they produce no lasting harmful effects, and that a man's efficiency after an attack is not much more reduced than would be the case after the loss of the same amount of sleep as is usually involved in an attack.

Dr. G. B. Cowell, of Bridgeport, Conn., one of the rolling-mill centers adjacent to the Naugatuck Valley, became interested in the subject of "brass shakes," as his father and two brothers were casters, and he himself had worked at the trade in his college vacations. No cases had come to him for professional treatment, as the men afflicted almost never seek medical aid. However, he sent out a list of questions to 20 representative brass mills of his district, asking information on the number of casters and caster's helpers employed, their age, the length of time they had worked at the trade, data on the illness or death of casters, influence of the use of alcohol, preventive measures, etc.

As the professional standing of Dr. Cowell and the accuracy of the data collected by him have been vouched for by half a dozen men of high standing in the rolling mills of that district, his data should be of interest. He obtained figures on 206 casters and 145 helpers, finding 1 caster who was 80 years old and had been a caster for 50 years, though not then actually in the mill, as he had been incapacitated by a fall. Two others had worked at the trade for 40 years, 14 for 30 years, and 66 for 20 years. Five casters were 60 years of age, and 20 over 55. The ages were in full:

Period of service of workers in the rolling mills of one district.

Years.	Number of casters.	Number of helpers.
20 to 30...	18	51
30 to 40...	76	56
40 to 50...	72	32
50 to 60...	35	4
60 to 70...	5	2

The death rate from consumption among casters is given by him as 2.5 per 1,000, and the general figure for Connecticut as 4 per 1,000. He finds the average air space per worker in the 20 casting shops to be 9,697 cubic feet per man, ranging, in 19 cases, from 18,000 to 4,200 cubic feet per man. The air space required in English casting shops is 3,500 cubic feet per man. One plant fell to 2,375 and its

workmen had trouble from the "shakes." Habitual users of alcohol, he finds, are liable to more frequent and more severe attacks of chills than are abstainers or moderate users. Connecticut casters as a class, however, bear about the same relation to the average brass-mill worker as the members of the football team do to the average student body of a university, so that comparative figures for death rates or ages are not conclusive as to the effect of "brass shakes" on the average men. Yet it seems probable that the high temperatures in which the casters work and the effect of going out doors in winter while perspiring freely, as casters commonly do, may have as much to do with the commonly alleged liability of brass melters to consumption as do the attacks of "brass shakes."

That the harmful effects of "brass shakes" are not to be classed with those of other industrial poisonings, such as by lead and phosphorus, is indicated by that fact that such good authorities as Winslow[a] and Tolman and Kendall[b] do not specifically mention "brass shakes." Winslow merely states that among a list of other metals zinc is responsible for more or less trade disease.

Whatever view be taken of the ultimate effect of repeated attacks of "brass chills," they are unpleasant, probably decrease the efficiency of the worker immediately after an attack, and may possibly decrease the bodily resistance to other diseases.

Hence, although it is manifestly unfair to the brass industry to class "brass shakes" with lead or phosphorus poisoning, yet every precaution should be taken to prevent them.

PREVENTION OF "BRASS SHAKES."

To prevent the "shakes" the zinc fume must not be allowed to enter the nose or mouth. The use of respirators is possible, but they are seldom employed, as the men prefer an occasional attack rather than the continual discomfort of wearing the respirator. A few plants report that respirators are provided free for those who wish them, and in two plants their use is compulsory whenever yellow brass is poured. As enough fume to develop immunity is not present in foundries where yellow brass or manganese bronze is seldom poured, and as the small amount produced would not warrant installing forced ventilation, the inconvenience from "brass shakes" may be as great and the cases as many as in rolling mills where alloys high in zinc are constantly poured, but where there is proper ventilation and where immunity is developed. Hence in the plants where alloys high in zinc are poured only occasionally, the wearing of respirators during such pouring should be made

[a] Winslow, C. E. A., The prevention of industrial poisonings: Proc. 8th Int. Cong. App. Chem., 1912, vol. 26, p. 309.

[b] Tolman, W. H., and Kendall, L. B., Safety, 1913.

compulsory. As the toxicity of the zinc fume probably exists whether the fume be inhaled or swallowed, eating food or chewing tobacco in the presence of zinc fume or without previous washing of the hands and face should be prohibited.

Some of the fume may be caught by the use of a cover placed over the pouring ladle or crucible and having a small opening to allow pouring of the metal. One form of such a cover is described

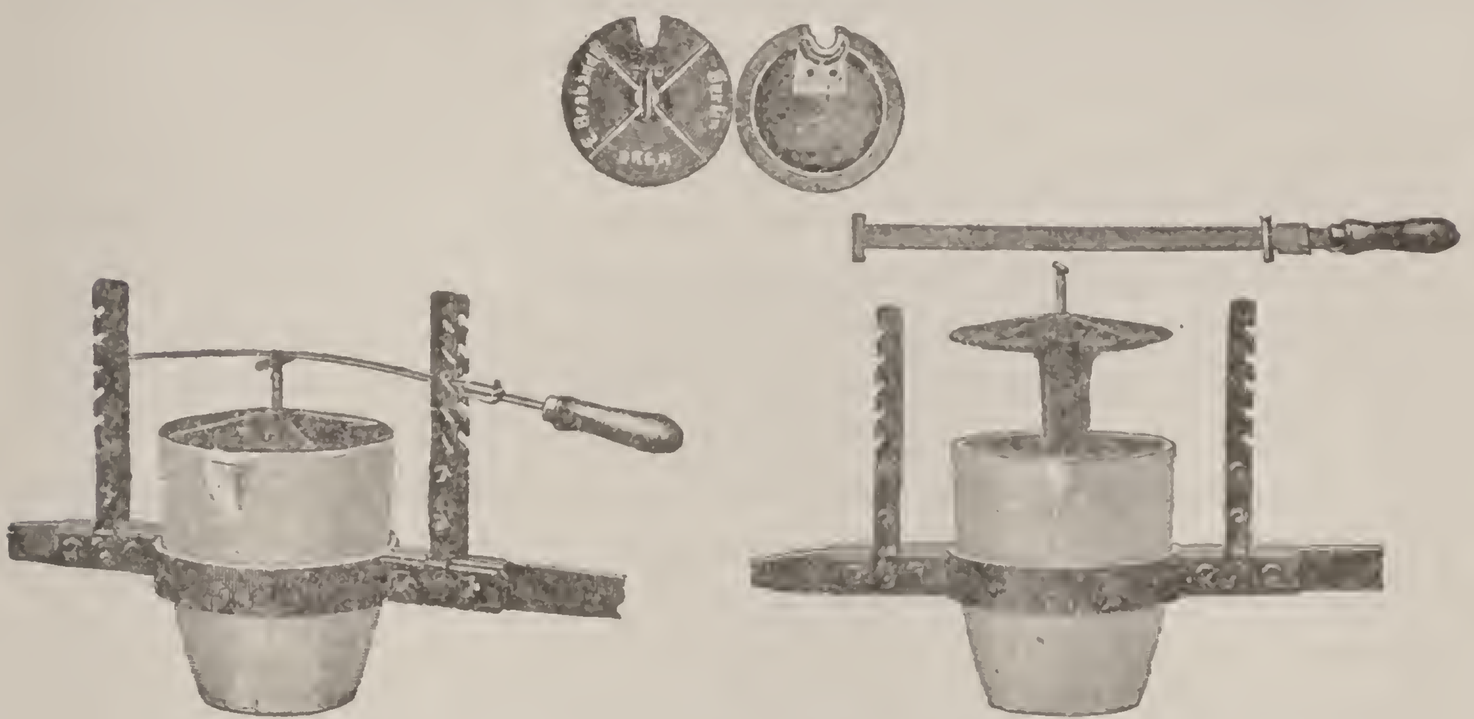

FIGURE 22.—Covers for pouring crucibles or ladles to hold back zinc fumes.

by Primrose,[a] another is on exhibition at the American Museum of Safety, New York City, and still others are on the market; two forms are illustrated in figu es 22 and 23.

A firm that has tried one such cover, which was designed to skim the metal during the pouring as well as to hold back fumes, reports that the cover did not properly skim the metal and that its use involved considerable trouble; hence it was discarded. As this firm does not cast yellow brass, it did not consider itself in a position to decide whether the holding back of the zinc fume would outweigh the trouble involved in using the cover.

FIGURE 23.—Another type of cover for holding back zinc fumes.

No trouble from "shakes" is reported from any plants dealing only with bronze, red brass, or other alloys low in zinc, save for one isolated case where cupronickel, free from zinc, was melted in a battery of furnaces sometimes used for yellow brass, but no alloys containing zinc were being melted at the time the attack was contracted. The symptoms were thought to be the same as in the ordinary "shakes." This is the only case of its kind reported, and in general no trouble need be feared from red brass and little from "half yellow and half red" brass if ventilation is good and the pouring temperature low.

[a] Primrose, H. S.. Discussion of modern brass founding: Foundry, vol. 40, 1912, p. 366; Castings, vol. 10, 1912, p. 174.

In dealing with "half yellow and half red" alloys poured very hot, with yellow brass, manganese bronze, or German silver, the men should be warned against inhaling zinc fume, and advised to use respirators (which should be provided free by the management) and to drink milk to alleviate the "shakes," and should be told that the use of alcohol makes them more likely to have the "shakes." Notices containing such information should be posted or given to the men.

One notice used for this purpose is as follows:

> CAUTION.
>
> The fumes given off during the melting and pouring of brass, lead, tin, antimony, zinc, or bismuth are poisonous, and should be avoided as much as possible.
>
> Excessive inhalation of the fumes of these materials may be the cause of mild forms of metallic poisoning, indicated by temporary illness, such as the feeling of exhaustion, nausea, marked pallor, and chills.
>
> REMEDY.
>
> Hot, nonalcoholic drinks and induced perspiration.

PROPER VENTILATION.

The main preventive is such good ventilation that the fumes will be at once carried above the workmen's heads and out of the shop. That the "shakes" can be practically eliminated by proper ventilation is shown by some dozen replies to the effect that, though the firms represented deal with yellow brass or manganese bronze, by reason of ample ventilation no cases have occurred. Several state that although "shakes" used to be common, the trouble has ceased since the firm represented has moved into a new, properly ventilated foundry, or since suction ventilation has been installed. If "brass shakes" occur they are prima facie evidence that the ventilation is not adequate. Few plants acknowledge continual trouble from "shakes," most of them replying "rarely," "seldom," "only on muggy days," "only on dense days in winter when the windows can not be opened," "beginners only affected," "only whisky users," etc. One reply states that when unhooded furnaces were used, 15 per cent of the workers were affected; another, "common during winter"; another, "on Monday nights in cold weather"; another, "10 per cent of the men have them on Monday night in winter"; and the last acknowledges notable trouble, and says, "Our men had the 'shakes' three times a week on the average before our ventilating system was put in; now they average only once a week, and we are

increasing the capacity of the ventilating system in order to eliminate them entirely."

One firm found that after ample ventilation had been provided not only did the workers cease to be troubled by "shakes," but the drunkenness among the workmen was greatly decreased. The improvement is ascribed to the absence of zinc fume, and hence of the "shakes" and the use of alcohol as a remedy.

To insure good ventilation high roofs are essential. The foundry or casting shop should always be either in a high one-story building, or on the top floor of a building of more than one story. In either case, monitor roofs or similar roofs providing for ample ventilation should be used.

Natural ventilation is usually adequate for removing dust and fumes other than zinc fumes from foundries where no alloys high in zinc are cast. If yellow brass or manganese bronze are poured, no plant should rely on natural ventilation alone, as on dark, quiet, muggy days, even with all ventilators open, the fumes do not rise promptly enough.

Forced ventilation is advisable in all melting rooms, though the warm air always present greatly aids natural ventilation if proper hoods are used. Whenever possible, the melting room should be separate from the foundry. If the furnaces are in the body of the foundry, each should have over it a hood coming down as near to the furnace as practicable. If the furnaces are in one end of the foundry, an apron should be placed across the whole end in front of the furnaces and extending to within about 8 feet from the floor. If the furnaces are of the pit type, and permanent hoods do not allow room for lifting the pot or do not allow sufficient room for operating the crane, swinging or telescoping hoods should be used.

Any type of furnace can be so installed or hooded as to eliminate zinc fume. Hence the problem of "shakes" need have little to do with the choice between different types of furnaces.

The main trouble is in pouring, and accordingly the pouring floors should be amply ventilated. Suction fans are the most common means of obtaining forced ventilation. They are put preferably in the roof, but are sometimes placed in the side walls, where they should be at least 12 feet from the floor. They must be of ample size to keep all fumes lifted above the workmen's heads.

With natural ventilation only much trouble is experienced in the winter, particularly when cold weather first sets in, for the workmen will not open the ventilators if, as a result, the shop will become unbearably cold.

Hence the problem of "brass shakes" resolves itself into one primarily of adequate ventilation for muggy days, but just as truly into one of adequate heating for cold days. Probably not one foundry in

ten is properly heated in winter, and many an otherwise up-to-date foundry will be found in which stoves or salamanders are used in order to keep the molding sand from freezing at night and the molders' hands from being too numb to hold a slick in the daytime. This condition exists in spite of the fact that in almost any plant the waste heat from the furnaces could doubtless be so applied as to give entirely adequate heat. The salamanders are often unhooded, and as coke high in sulphur is burned in them, the CO and SO_2 produced are almost unbearable.

The use of heaters discharging smoke or gas into the foundry is prohibited in New York State by recent legislation.

Aside from the better ventilation, made possible by adequate heating, and the greater productivity of the men working in a normal temperature, it should not be forgotten that cold sand is a prolific cause of "blows" or other foundry troubles. It may not be easy to make a balance sheet show that in the long run the proper heating of a foundry will pay, quite aside from the moral obligation of an employer to provide proper heat out of regard for the health of the workers, but such is certainly the case. The minimum temperature on the coldest days should be 50° F.

MAINTENANCE OF PROPER TEMPERATURE.

The indirect-air system of heating is giving good results in many foundries.[a] Pure air is drawn in by a large blower, is warmed by being passed over suitable heating coils or radiators, is forced through large pipes overhead or along the walls, and is then delivered to all parts of the foundry in large volume but at low velocity. Roof ventilators or suction fans remove the air after it has given up most of its heat. This system provides not only heat but also ventilation.

The air may also be regulated as to humidity, and it is quite possible that the heating coils might well be replaced in summer by some refrigerating device to cool the air. Nearly every foundry has to close on a few of the hottest summer days, either because the management is unwilling to allow the men to work in temperatures liable to cause heat prostrations or because the men refuse to work. "Breaking the heat," as quitting work on account of the heat is commonly called, is known in most foundries. The loss occasioned by a few days of inaction from this cause might easily pay for the cost of the cooling device, to say nothing of the advantage a plant known to be cooling its foundry would have in obtaining efficient labor.

Recent legislation in New York requires the maintenance not only of proper ventilation but of proper degrees of temperature and

[a] See editorial, Heating and ventilation of a large foundry: Iron Age, vol. 91, 1913, p. 415.

humidity. Suction devices for removing fumes, proper hoods, and special means or devices to reduce excessive heat are also required.

To maintain a reasonable working temperature, a mild blast of air, either over the furnace tenders' heads or directed downward to the floor back of them, but not directly on them, when working at the furnaces, is necessary in summer with most types of furnaces, especially when the furnaces are close together.

LEAD AND PHOSPHORUS POISONING IN FOUNDRIES.

Lead poisoning is rare in regular foundry work. Four plants have reported cases that are traceable either to the melting of bearing bronzes high in lead, or to the refining of lead dross and scrap in foundries having smelting departments.

In one case of lead poisoning the trouble was traced to a lead kettle operating on a lower floor, in a room with a low ceiling and without adequate ventilation. Thompson[a] cites several cases of lead poisoning among men working in smelting works, and found one case of a man working with brass and composition metal containing lead.

No lead poisoning has been traced to alloys of the normal composition having, say, less than 8 per cent of lead. Great care should be used in handling or melting alloys high in lead, or in the use of corroded scrap lead. Where conditions prevail that make lead poisoning possible, the men should be instructed of its dangers, and notices posted or given to the workers, containing such information as is given on the following notice, which, in New York State, is urnished free by the State department of labor, and is printed in other languages as well as English.

HOW MEN ARE POISONED BY LEAD.

(1) Lead is poison to the body. It enters the body mainly through the nose and mouth. It may be inhaled as dust or in fumes. It may be swallowed with food or saliva (especially if tobacco or gum is put into the mouth with soiled fingers). Or it may sometimes be absorbed through the skin.

(2) When lead gets into the body, it leads among other things to indigestion and lead "colic"; to diseases of the heart, blood vessels, and kidneys; or to paralysis of the hands, known as "wrist drop."

(3) Lead acts upon the body slowly and insidiously. Without knowing your danger you may be getting some lead poison into your body every day. If you are working with lead in any one of its many forms, you must therefore use great care so as to protect yourself against it.

(4) *On the very first sign of not feeling well, see a doctor or go to a dispensary. Do not wait until you are too sick to work. The earlier you go to a doctor, the easier it will be to cure you if you are being poisoned by lead.* BE SURE TO TELL THE DOCTOR ALL ABOUT YOUR OCCUPATION AND ITS DANGERS.

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[a] Thompson, W. G., Industrial lead poisoning: Proc. 8th Int. Cong. App. Chem., 1912, vol. 16, p. 53.

HOW TO PREVENT LEAD POISONING.

(1) Always wash before eating and, if you work in a factory, before leaving the factory.[a] Remove all dirt from under your finger nails with a brush.

(2) Never eat in the room in which you work.[b]

(3) Never chew tobacco or gum while working. If you do, the lead dust on your fingers and in the air is sure to be swallowed.

(4) Use overalls when you work. Do not wear your working clothes on the street or at home. They may contain lead and poison you and others.

(5) Respirators are very useful and should always be used when working among lead dust or fumes.

(6) Keep the workroom clean. Do all you can to keep down dust. Do not get lead on your hands and clothes any more than you can possibly help.

(7) Always eat a good breakfast before going to work. Drink plenty of milk. Have at least one good movement of the bowels every day. Constipation is a suggestive symptom of lead poisoning. Avoid the use of intoxicants in any form. Their use weakens the body and makes it harder for your body to overcome the poison of lead.

(8) Keep clean. Wash with warm water, soap, and nail brush. Take at least one full hot bath a week.

Other notices sent the bureau by foundries describe the symptoms—a blue line on the gums, accompanied by debility, loss of appetite, sick stomach, headache, colic with constipation, and wrist drop preceded by pain or numbness in the forearm. The wearing of gloves, the protecting of all cuts and scratches until healed, and prompt attention to decayed teeth are also recommended in some of the notices.

A full discussion of industrial lead poisoning and striking photographs of men afflicted with it are given by Hamilton.[c]

No cases of phosphorus poisoning in foundries were reported. Where phosphorus is used as a deoxidizer, red instead of yellow phosphorus may be used, or yellow phosphorus may be plated with copper or wrapped in tea lead. The covering of yellow phosphorus in this way is mainly as a preventive of burns from handling the phosphorus itself and from explosions when the phosphorus is put into the copper or bronze. The precautions against poisoning from phosphoric acid fumes are ample ventilation and the compulsory use of respirators.

METALLIC DUST AND SIMILAR IRRITANTS.

The term "brass poisoning" is often loosely used to include not only "brass shakes," but also the troubles arising from inhalation of metallic dust from emery grinders, from polishing and buffing devices,

[a] In factories the labor law requires employers to furnish washing facilities, including hot water and individual towels.

[b] The labor law forbids any worker to take food into any part of a factory, shop, or working place where lead is present in "harmful quantities."

[c] Hamilton, A., Investigations on lead troubles in Illinois: Report of Illinois Commission on Occupational Diseases, 1911, p. 21.

etc. Hoffman[a] states in regard to "brass shakes," or "brass founders' ague:"

> Zinc and other fumes inhaled are the chief causes of this ailment, and it is quite probable that the lung injury resulting from the inhalation of fine particles of metallic dust is a material contributory cause in brass founders' ague.

In few plants, however, are men exposed both to zinc fume and to metallic dust; hence the two troubles should be differentiated.

Hayhurst[b] more properly terms poisoning from brass dust "pseudo-brass poisoning," and also states that direct toxic effects of inhalation of cold metallic brass dust are mechanical only, and do not produce the "shakes," and that troubles from brass dust fall into much the same class as those from iron dust or stone dust, although much of the inhaled dust is swallowed, and brass dust may then produce the poisoning shown by copper, zinc, or lead compounds when taken into the stomach. That considerable copper finds its way into the system of a grinder is shown by the fact that a grinder's hair and teeth often show a greenish tinge, and his perspiration may also be distinctly green. These effects are not seen in brass melters. The evil effects of the inhalation of brass and emery dust have been clearly shown by Hoffman[c] and must be apparent to any one. Sand blasting without the use of precautions to prevent the inhalation of the sharp sand particles falls into the same category and is reprehensible in the extreme.

Trouble from these causes may be entirely avoided by the use of suction hoods on emery wheels or polishing and buffing wheels. It should also be pointed out that the more complete recovery of the grindings by an exhaust collecting system goes a long way toward paying for its installation.

Full specifications for the design, construction, and operation of exhaust systems for grinding, polishing, and buffing wheels have been issued by the New York State Department of Labor.[d]

Sand-blast rooms separate from the rest of the foundry, helmets for use therein, sand-blast tumbling barrels, and various mechanical means for sand blasting without making it necessary to inhale any of the dust are common. The protection in grinding, polishing, or sand blasting may in many cases be made sufficient so that the use of a respirator is not necessary. Unless other means are fully adequate, respirators must of course be supplied. The evil effects of the dust rising from the knocking out of cores from the castings and from

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[a] Hoffman, F. L., Mortality from consumption in dusty trades: Bureau of Labor Bull. 79, 1908, p. 662.

[b] Hayhurst, E. R., Occupational brass poisoning—Brass founders' ague: Am. Jour. Med. Sci., vol. 145, 1913, p. 724.

[c] Hoffman, F. L., loc. cit.

[d] See also Foundry, Data sheets 137-143, vol. 41, 1913, May, June, July, and August; Industrial Engineering, vol. 13, 1913, p. 211; Brass World, vol. 9, 1913, p. 102.

the preliminary cleaning of castings before cutting or sawing off sprues, grinding, or chipping should be mitigated by forced ventilation in the knock-out room, and by frequent sprinkling of the floor with water. Knocking out on gratings helps to reduce the accumulation of dust. The knock-out gang should be provided with respirators and goggles. Goggles or eye protectors should always be supplied to grinders and their use made compulsory.[a] Glass eye shields in front of the emery wheels are sometimes used.[b] A pertinent notice posted in one plant is as follows:

> SHOP RULES—SAFETY FIRST.
>
> Do not wear gloves while working around a machine while it is in motion. It is dangerous.
>
> Always wear goggles, which will be furnished you, when working cast iron, brass, Babbitt metal, or when using emery wheel—they may save the loss of an eye.

Plate I shows an illustration used in one firm's booklet of rules for protection against injury. The plate shows hooded emery wheels and the goggles provided for grinders. Dark goggles should be supplied to furnace tenders. Grinders and chippers may well be provided with an iron-studded leather apron for protection from mechanical injuries when a casting on which they are working slips. Gloves should be provided for men handling pig metal.

Pickling, plating, and lacquering also involve harmful acid spray or gases that are somewhat poisonous. As these are not operations included in foundry work as such, they may be dismissed with the remark that adequate hoods and exhaust ventilation, as well as the use of rubber gloves to protect the hands from acid solutions, are required.

PROPER LIGHT IN FOUNDRIES.

Although modern foundries are being constructed with ample light for daywork, many of the older ones are extremely ill lighted. Whitewashing[c] the walls at least twice a year is practiced with great success in up-to-date plants, although some foundry owners consider it impractical. It is not impractical, however, as those who do it testify that the expense, when air sprayers are used, is slight compared to the benefits, as in all modern foundries compressed air is available for molding-machine operation. The New York State labor law provides that the inspector may, in his discretion, require that walls and ceilings be whitewashed. Some plants make a com-

[a] Cameron, W. H., How to prevent blindness among your employees: Foundry, vol. 41, 1913, p. 582.
[b] Pultney, D. C., Safeguarding factory tools and equipment: Electric Jour., vol. 9, 1912, p. 602.
[c] See Kitson, A., Foundry and workshop lighting: Metal Ind., vol. 11, 1913, p. 383.

WORKMAN WEARING GOGGLES. NOTE HOODED EMERY WHEEL.

plete clean-up whenever they whitewash, all accumulated dust being removed from the foundries, and these plants find that the clean surroundings are conducive to better and more careful work. Frequent window washing also is of great benefit. It is a common thing to see a molder spend ten times as long in taking loose sand from deep places in his mold as it would take him were adequate light supplied, and he often does as much damage as he repairs. As damp molding sand is dark in color, poor light makes unusually deep shadows. Windows in the roof, as well as walls that are half or more glass, are provided in the most modern plants. To get roof lighting in a building of more than one story, as well as for better ventilation, the foundry should be on the top floor. This location is usually best also as regards routing the product, the rough castings going down story by story through the finishing process in proper sequence.

The artificial lighting of the foundry is seldom adequate. Abundant and diffuse lighting is best. A single dirty incandescent bulb somewhere near a molding bench is often all that is supplied. Diffuse lighting in order to allow the inspection of deep pockets in a mold is absolutely essential.'

For small flasks on bench work, individual Tungsten drop-lights or gas arcs may sometimes be adequate, but for large floor work, diffuse illumination is required. The soft and diffuse light of the mercury arc is considered by some plants to be ideal for such work. Flaming arcs are also used, but cast rather more shadow.

Proper lighting will pay and pay largely in the shape of fewer spoiled molds and scrap castings.

PREVENTION OF BURNS.

The most serious of all the hazards of the foundry and casting shop is that of burns from molten metal. The loss of an eye or even of life has come from putting damp metal, a damp skimmer, or damp gates into molten metal, and every precaution against such action should be taken. Skimming into water is dangerous. Aside from cases of this nature, the main danger is from burning the feet or legs by metal spilled at the furnaces, in the gangways, or at the mold.

A shallow pan filled with sand and set into the floor an inch or so, but level with it so it will not be stumbled over, lessens the spattering of metal spilled from the lip of a tilting furnace while being poured into the ladle.

In adding zinc (speltering) the zinc should be warmed well before being put into the molten metal, it should be introduced gradually, and the metal should be slowly stirred. If the zinc be added too rapidly, so that it boils, an explosion similar to that from adding damp metal may occur and the entire furnace contents be thrown over the melter.

Gangways must be kept clear. All workmen should be made to realize that skimmers, gates, or anything over which the metal carriers might stumble if thrown into the gangway may cost a fellow workman's life or maim him terribly.

The filling of ladles so full that the metal is likely to slop out or running with a ladle of metal is dangerous. Metal carriers should understand that when two or more men are carrying a ladle shank the ladle must not be dropped no matter what happens. Each should hold it until he can tell the others that he is about to set it down. If he drops it, he is certain to be injured and the other men are in nearly as much danger. If crucibles in shanks are used as ladles, they should be securely wedged in—or, better, held on by a clamp—and should be properly balanced so that the center of gravity is low. If ladles are carried on overhead trolleys, a gong which may be made self-acting should be rung continually to indicate that a ladle of molten metal is coming. Crane tracks must be constantly inspected for loose bolts. Flasks should be maintained in repair, and the flasks should be properly weighted or clamped so that run outs will be prevented.

After all precautions possible have been taken to prevent spilled metal, the next essential is that the workmen wear such trousers and shoes as will prevent spilled metal from causing serious burns. Furnace tenders, metal carriers, and molders are all liable to burns of the feet and legs from spilled metal and run outs.

Ragged trouser legs, low shoes, lace or button shoes, shoes broken at the toe, or congress shoes with gaping tops, all hold spilled metal and make serious a spill that would be practically harmless with proper pants and shoes. The wearing of congress or molders' shoes, or else asbestos gaiters, over the calf, ankle, and instep should be obligatory. Molders' shoes are bought in large quantity by many firms and sold to the workmen at cost. If a man does not wish to buy his own congress shoes from a dealer or from the company at cost, and insists on wearing out an old pair of lace shoes, he should be forced to wear asbestos, canvas,[a] or leather gaiters supplied by the company. The right and the wrong kind of shoes are shown in Plate II, *A*.

Asbestos aprons extending to the knee, and trousers faced with asbestos from the knee down, should be supplied to furnace men and metal carriers by the company. Care must be taken that congress shoes have a good quality of elastic, so that they do not gap at the top before worn out, as bad burns have resulted from hot metal dropped into such a gap.

Bicycle clips are sometimes used by metal carriers to confine the trousers at the ankle and prevent them from catching on projections

[a] Outerbridge, A. E., Prevention of accidents in the foundry: Iron Age, vol. 92, 1913, p. 772.

A. RIGHT AND WRONG KIND OF SHOES FOR FOUNDRY WORKERS.

B. SHOE THAT ALLOWED WEARER TO SUFFER A SEVERE BURN FROM HOT METAL.

and causing a fall. If clips are worn, care must be taken that no pockets are formed by the folds that will retain molten metal spilled into them.

Some good rules for the avoidance of burns appearing in a safety booklet given to each employee in the foundry of one firm are presented below:

Rules for preventing burns.

Reporting accidents.—In case of injury, no matter how slight, even a slight cut or burn, report at once to your foreman. Sometimes a slight cut or burn will result in blood poisoning if neglected.

Examine ladle and skimmer.—Examine carefully the ladle or skimmer before using to see that it is not damp or wet. A damp or wet ladle may cause an explosion.

Filling ladles too full.—Do not fill your ladle too full, as you are liable to spill its contents and receive serious burns.

Catching metal.—In catching metal from tilting furnaces men must be careful to handle their ladles in such a way as to cut the stream in toward the furnace.

Turn out to the right.—In gangways always turn out to the right, and when you meet a man carrying a ladle of hot metal give him plenty of room.

Foot near mold in pouring.—In pouring metal into molds be careful not to have the foot too near the mold; also be careful not to get into such a position as to make it hard to get away quickly should the metal break through the mold. Many serious burns of the feet have been caused in this way.

Explosion of gases.—When pouring large flasks or molds, the gas must always be lit to save an explosion that is liable to occur from the dampness of the sand in the mold.

Pouring hot metal or slag on damp ground.—Great care must be taken not to pour or spill hot metal or slag on the damp ground or in vessels in which there is water. If you do, an explosion may occur and you may be seriously injured.

Obstructing gangways.—Workmen are forbidden to leave in the gangways weights or other material over which men may stumble and fall.

Don't run with a ladle.

Don't drop a ladle.

Keep pants repaired.—Workmen must keep their pants repaired from the knee down and around the bottom, so that the legs and feet will be protected from the hot metal if it spills.

Congress shoes.—All foundry men must wear congress shoes. (Many men wearing lace shoes have had their feet seriously burned because they could not take the shoes off quickly enough or because the hot metal burned through the open part where the laces cross.)

Inspection of crane tracks.—The crane tracks must be inspected every two weeks for broken or loose bolts.

The firm issuing the rules quoted also issues at intervals a safety bulletin to its employees. A significant quotation is as follows: "When caution becomes a habit, there will be few accidents."

In one issue of the bulletin the firm mentioned reproduced the photograph shown in Plate II, *B*. The plate shows a shoe the wearer of which suffered a serious burn, causing the loss of 60 days' time. The only place at which the shoe is burned is at the little toe. Had this been a good, strong shoe the injury would have been slight, but owing to the broken condition of the shoe, the metal poured in the

break all across the top of the foot, seriously burning all the toes. As the shoe was of the button type, the employee could not remove it quickly, as he could have done had he worn congress shoes.

No amount of ordinary notices or verbal warnings can be as impressive as such an illustration as this presented to employees.

One foundry posts the following well-worded notice:

WARNING.

Most of the serious accidents that have recently happened in this foundry would have been prevented if proper shoes had been worn.

The company will furnish such shoes at cost if desired, but will be quite as well pleased if employees will purchase them elsewhere.

The point is:

Wear molders' shoes and avoid danger.

Asbestos gloves should be provided for furnace tenders and metal carriers.

Great care should be taken in the use of gasoline for drying molds or green sand cores. Gasoline torches for "skin drying" should be used with caution. Gasoline torches, or large torches using fuel oil, should not be filled in the foundry, or by the users, but in a place away from flame and by the stock keeper.

In one instance the oil in a large torch was used up, and, rather than go to the stock room for more, a molder dumped gasoline into it from a small torch. An explosion resulted that set the clothes of two workmen afire. One of them ran down the gangway, thus fanning the flame; the other was caught and rolled into a pile of molding sand. The first was badly burned, but the second escaped with only slight burns.

TREATMENT OF BURNS.

Neglect of slight burns may result in blood poisoning; hence even the slightest burn should receive prompt attention. One notice posted in regard to treatment of burns follows:

NOTICE.

REGARDING BURNS FROM MOLTEN BRASS.

If the burn is slight, wash it first with a warm solution of a mixture of 50 parts of water, containing 2 per cent CARBOLIC ACID, and 50 parts of a strong solution of SODIUM CARBONATE. After the pain has subsided, apply a bandage saturated with a mixture of 80 per cent strong LIME WATER and 20 per cent boiled LINSEED OIL. After the blister that forms has broken or been reduced, the burn should be dressed with HYDROGEN PEROXIDE diluted with one-half water, and the wound will heal.

If the burn is serious, call a physician, and, pending his arrival, apply the CARBOLIC ACID, and leave the rest of the treatment to the doctor.

The New York State law now specifies as follows:

There shall be in every foundry, available for immediate use, an ample supply of lime water, olive oil, vaseline, bandages, and absorbent cotton, to meet the needs of workmen in case of burns or other accidents; but any other equally efficacious remedy for burns may be substituted for those herein prescribed.

An emergency case with suitable supplies for the first treatment of burns should be in every melting room, and the foreman should be taught how to use the supplies. This advice holds even if there is an emergency hospital connected with the plant, as preliminary treatment should not be delayed.

DANGER FROM MOVING MACHINERY.

The safeguarding of moving machinery to prevent injury is as essential in the foundry as in the machine shop. As the foundry proper seldom contains much machinery, the main things to be safeguarded are band saws, sprue cutters, emery wheels, elevators, hoisting shafts, core-sand mixers, and, in particular, the woodworking machinery of the pattern shop.

One foundry visited used an unguarded band saw, but the manager promised to guard it at once. All belts and gearing should be guarded, whether in the power house, sand-mixing room, grinding room, or foundry proper.

Notices should be posted and employees warned regarding suspended crane loads, and cranes should bear a gong to be rung whenever the crane is carrying a load.

DANGER SIGNALS.

At any places where danger exists, such as at the door between the melting room and the foundry where a workman may be suddenly met by a metal carrier with a ladle of hot metal, if the layout of equipment can not be so planned as to give a clear view, large red signs bearing in English, and in the language of any foreign workmen employed, the legend "DANGER—Look out for the metal carrier," or "Look out for——," whatever the hazard may be.

There are times in all foundries when alterations have to be made while the plant is running, when safety devices have to be temporarily removed for repair, or when workmen may be temporarily doing overhead work, so that tools, etc., are liable to be dropped. The approaches to places where such temporary hazards exist should be marked by red flags, to indicate danger. Notices should be posted of this nature: "Caution—*Red* on machines and appliances means DANGER." Repair work requiring men to work above furnaces should not be done while the furnaces are running, or while they are hot.

Great care should be taken that flasks and castings stacked on trucks or other materials are securely piled, so that they may not fall on workmen. Broken legs or more serious injuries may result from neglect of this precaution.

Boards with nails in them should not be allowed to lie where they might be stepped on. Wrestling, scuffling, throwing sand, or horseplay of any sort is dangerous and should be prohibited in the foundry, even outside of working hours.

BATHING.

As foundry work, even with all reasonable precautions, is of a dusty nature and induces perspiration, suitable bathing facilities should be provided. These should not consist merely of a pail of water drawn from a faucet, but should embrace enough individual basins, or sinks, so that each man may wash without having to wait long for his turn. Soap, hot water, and individual towels are essential. These are all required by New York State laws. Illinois laws specify also nail brushes and nail cleaners, and one water spigot to every six employees, and make it illegal for the workmen to eat without washing their face and hands and cleaning their nails. Moreover,

the Illinois laws require shower baths sufficient to allow each employee a shower bath once a day, when the inspector deems them essential.

The provision of bath towels is also specified. The Illinois laws further specify that proper working clothes must be provided without cost to the employee and must be kept reasonably clean by the employer. On visiting some Illinois foundries, the author found that this provision of the law was not being rigidly enforced, although several of the larger foundries were willingly complying with it.

The New York laws require that suitable provision be made for drying the working clothes of foundry employees. Separate lockers for street and working clothes are provided by some plants, and are advisable. If such lockers are not used, one well-ventilated locker for each employee should be provided.

The most progressive plants allow the workers sufficient time to wash, on company time, at noon and night. The following notice, taken from a booklet given to the employees of one firm, gives good advice, and might well be posted in all shops.

HEALTH.

Foundry employees are particularly warned of the danger to their own health of leaving the molding rooms and exposing themselves to the weather until after they have cooled off and clothed themselves properly. A good practice to follow before leaving is to use the wash rooms provided.

EATING IN THE FOUNDRY.

Both New York and Illinois absolutely prohibit eating in the foundry. New York requires that suitable quarters be maintained to enable the workers to take their meals elsewhere in the establishment. Illinois specifies lunch rooms wherever practicable.

Eating amid the dust and fumes of the foundry is plainly objectionable, as is the handling of chewing tobacco without washing the hands. The practice of allowing a period of 10 or 15 minutes in the middle of the morning for the eating of food brought into the foundry, which is a relic of days when the hours of labor were much longer, and is still common, especially in some parts of the Middle West, is reprehensible, as it does not allow time enough for the workers to go to and from the lunch room, and means that food is eaten amid dust and with dirty hands. Such a recess is hardly necessary with modern hours of labor, but, if given, should be long enough to allow washing and the use of the lunch room.

If washing before eating is required by law, the employer is of course able to enforce such a rule. In States where there is no such legislation some employers report far less difficulty in enforcing such a rule than they had imagined would be the case.

MISCELLANEOUS EQUIPMENT AND PRECAUTIONS.

The following should be provided in every foundry: Respirators, goggles, and leggings to those whose work requires them; an adequate number of wash basins; hot and cold water; soap; nail cleaners; individual towels; shower baths; well-ventilated individual lockers; dressing rooms; lunch rooms provided with sufficient tables and benches to accommodate all workers.

The weekly washing of the work shirt and trousers of each employee at company expense might also well be provided for. Time for washing at noon and night should be allowed. There should be an absolute prohibition against eating in the foundry or without washing. The supplying of hot coffee and milk at cost is advisable, and in many localities remote from restaurant facilities, or where those near the plant are of low grade, it is wise to have a company lunch room where hot meals may be obtained at cost by those who do not wish to carry lunches or prefer a hot meal.

It should be unnecessary to mention that all toilets and urinals should be kept clean and properly disinfected, and should be far enough removed from the workrooms so that the offensive odors will not be present in the workrooms. A surprisingly large number of foundries, however, neglect these elemental sanitary precautions.

As the heat of the foundry and the perspiration induced require the drinking of a large quantity of water by the workmen, particularly the furnace tenders, the purity of the water supply must be beyond question. Furnace tenders and casters who use alcohol to excess almost always have digestive or intestinal troubles in hot weather, and although these probably can not be entirely eliminated from the heavy drinkers, a pure water supply will lessen them. One plant reports that colic or cramps were very common with its workmen until the water was filtered and the method of its cooling changed from direct to indirect icing. The water should not be cooler than 48° F.[a] Sanitary bubbling fountains cooled without direct contact with ice and fed by pure water are necessary. If the water supply is not beyond question, or can not be made so by filtering, use should be made of bottled spring water or distilled water.

[a] Tolman, W. H., and Kendall, L. B., Safety, 1913, p. 17.

MEDICAL ATTENDANCE AND INSPECTION.

Illinois requires that brass-foundry workers be examined once a month, and preferably once a week, by a regularly licensed physician, and a report made by him to the State board of health in regard to any workers suffering from occupational disease. Such workers may not be kept at work but must be transferred to work at which exposure to the factors causing such disease is not involved.

An interesting case in one Illinois plant might be taken to show that foundry work is not necessarily unhealthful. A man working in the paint shop was found on one monthly inspection to be in the first stages of lead poisoning. He was transferred to the brass foundry (through an error), and at the next monthly inspection it was found that he was not only free from lead poisoning but had gained 20 pounds in weight.

A monthly medical inspection is a most sensible provision. A few of the larger manufacturing plants in other States, whose work includes casting or founding, accomplish the same ends more or less thoroughly by having a company physician, either permanently in residence at the plant, or making periodical visits. Some maintain company hospitals, with a graduate nurse in attendance. At the hospitals first aid is given in case of injury and treatment is made for colds, sore throats, or other minor ailments. At some of the hospitals the equipment is so complete that in an emergency major operations may be made.

Although a fairly large number of employees is necessary to make a plant hospital absolutely demanded, there is no good reason why many plants too small to support a hospital room should not be able to arrange for the establishment of a cooperative hospital room supported by several manufacturing plants situated near together. By thus dividing the expenses three or four adjoining plants could obtain the advantages of a plant hospital for their employees without involving any noticeable financial burden.

PROPER PERIOD OF LABOR.

No definite information as to the hours of labor was requested in the list of questions issued, but a statement as to the number of hours per day the furnaces were in operation was requested. In some plants the furnaces are not run all the working day, and in others they are started early. It is rather common practice to have the night watchman light coke or coal fires. Out of 205 replies to the question on hours per day per furnace, 25 report a run of more than 10 hours; 1 runs 24 hours in shifts, 65 report a 10-hour run, and 114 report a run of less than 10 hours, a 9-hour run being the most common, although there are a number of plants running on an 8-hour

basis. Nearly all of the 25 plants reporting a run of more than 10 hours use coke or coal furnaces, and it is probable that very few of these have over 10 hours of labor. The average time of running the furnace, as specified in all the replies, is well under $9\frac{1}{2}$ hours. It is therefore estimated that about half the plants reporting work 10 hours and about half either 9 or 8 hours.

FATIGUE AND OVERSTRAIN.

Rupture used to be common among molders and casters, but the advent of cranes and mechanical hoists has almost done away with this ailment. No plant doing heavy work requiring large copes or the handling of large crucibles can afford to be without adequate crane service. One plant posts the following notice:

> Don't try to lift on or off a cope that is heavy for you because you are in a hurry. Use the crane, call sufficient help, or call the foreman's attention to it.

Hayhurst [a] reports as follows:

> Workmen complain that they are now required to do from one-half to double again as much as they were wont to do 20 years ago. * * * There is considerable complaint among many brass molders of the constant physical and mental strain required at the present day. A foreman or other expert sets a pace on a certain class of work for a few hours' or a day's time, then men are compelled to keep up to this record daily. *Correction:* Limit the number of standard flasks or molds or their equivalents which a man should be expected to turn out in a day.

However, this condition is rare. Proper management holds that the maximum production possible by the use of improved appliances and scientific methods of time study, coupled with constant instruction of the men in the best and easiest ways of doing the work, is desirable, from the point of view, of both employer and employee. Waste of a workman's time through failure to give him full instructions as to the best way to do the work is as bad a violation of the principles of conservation as waste of fuel or metal.

Speeding, or pace-setting, used blindly to set a rate of production that is arbitrarily required, without giving the men proper equipment and constant instruction as to how to accomplish the task, is certainly reprehensible. However, time study and the devising of ways of eliminating waste motions often show that a man's production may be doubled and at the same time his hours of labor reduced and his physical exertion lessened, headwork by the management being substituted for much of the old handwork by the worker. The result may be an increase in wages for the workman in proportion to his efficiency. Hence, any arbitrary limiting of production is a step backward rather than forward. Hayhurst's suggested correction is

[a] Hayhurst, E. R., Investigation of the brass-manufacturing industry of Chicago: Report of Illinois Commission on Occupational Diseases, 1911, pp. 79, 81.

impractical, as there is no such thing as a standard flask or mold, all patterns varying in the amount and difficulty of the labor required. This suggestion was not incorporated in the Illinois law. The basic principle of the suggestion mentioned above, that of not forcing or inciting a workman to do more than he can with complete safety, is beyond reproach, though the suggestion was incorrectly worded.

Blakey [a] deals with this subject very sensibly when he says:

> Fatigue is one of the most important subjects which arises in the problems connected with industrial disease, because of its connection with the question of how many hours should constitute a day's work. This problem will never be determined scientifically or satisfactorily until adjusted according to the principles of physiological fatigue. Certainly everyone will admit that the capability for work varies according to the constitution, the age, the sex, the modes of life, and some allowance must be made for the individual capacity for work. On the other hand, no two occupations are identical in their demands upon physical or mental power. The man who works in intense heat should not have the same number of continuous hours as a carpenter at the bench; the textile-factory operator, who at her machine watches 16 to 18 needles for broken thread, with the severe strain thus imposed, should not have the same working schedule as the girl who sells goods behind a counter. Surely the hours of toil should be proportional to the nature of the work and as to its fatiguing character. No arbitrary rule can be made which will meet these demands.

One plant reports that in hot weather they "spell off" their furnace tenders, so as to reduce the danger of heat prostrations or weakening of the system. This precaution is admirable.

Much can be done toward eliminating fatigue and overstrain by the maintenance of proper shop conditions. It is quite possible to put up many more flasks a day in a shop that is well lighted and ventilated, kept cool, and in which good sanitation prevails, and with instructions on how to eliminate waste motions, than can be produced from the same pattern in a hot, poorly ventilated, poorly lighted, unsanitary shop in which the men are driven on by unscientific "speeding."

Much can also be done by fitting the man to the job—that is, by the exercise of common sense and a little applied psychology in the hiring of men and in assigning them to various forms of work. Men of slight physique, those liable to pulmonary troubles, or those of such nervous and excitable temperament that they are likely to lose their head in an emergency and spill molten metal on themselves or their fellow-workmen, should not be employed as furnace tenders, casters, or metal carriers. Yet these same men may, from their nature, be the most efficient workers at bench molding, core making, or other employments around the plant.

The work of Munsterberg is [b] of great interest in this connection.

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[a] Blakey, H. B., Occupational diseases: Bull. Ohio State Board of Health, 1913 (reprint), p. 6.
[b] Munsterberg, H., Psychology and industrial efficiency, 1913.

EMPLOYMENT OF WOMEN AND CHILDREN.

The foundry industry is practically free from reproach on the score of the employment of women or children.

Child labor in foundries is rare and is usually confined to time boys and boys who sort chills, core wires, etc. No boy should be allowed to work in a location exposed to zinc fumes, furnace gases, or at dusty work, without proper precautions being taken to lay the dust and to provide respirators. Women workers are found only in the core rooms. On small, light cores their dexterity and care make them far better workers than men or boys. Moreover, if the core rooms in which the women are employed are—as is almost always and should always be the case—separate from those in which male help is employed, if the rooms are well lighted, ventilated, and heated and free from furnace fumes or gases from the baking cores, if the women are not allowed to handle heavy core boxes or core plates, if stools are provided for their use, and if ample separate toilet facilities are provided, there seems to be no reason why core making should be any more detrimental to the health of women than clerking in a department store.

Most foundries employ women core workers for an 8-hour day only, and they come to work a little later and leave a little earlier than the men so as to allow the women to avoid the crowded transportation period. Their lunch hour is commonly different from that of the male workers. Many plants provide neat caps and aprons which are kept clean by the management.

POSTED NOTICES.

Of 230 firms represented in replies, 145 post no notices and do not mention giving verbal instruction to workmen in regard to hazards. Most of these state that there is no trouble from "shakes," either because no high-zinc alloys are melted, or because of ample ventilation. Several state that few men are employed, these well understanding the hazards; others state that no special hazard exists, or that no minors or foreign laborers are employed, the hazard of burns being neglected in such plants.

Sixty replies state that no notices are posted, but full verbal instructions are given, particularly to new men. About 25 post notices, 10 of these referring only to those notices required by the State laws. Fifteen post special notices, mainly giving such cautions against injuries as warnings against being under suspended crane loads, or cautions as to burns, with no mention of "brass shakes."

Notices ought to be posted in all foundries or casting shops warning against all hazards from mechanical equipment, from burns, against eating in the foundry or eating without washing, against exposure to cold air without first cooling off, and, wherever the possibility of

"brass shakes" or lead or phosphorus poisoning exists, against those troubles. The notices should be in all the languages of the workers employed. Red danger signs or flags should be used at points where permanent or temporary hazard exists.

Notices should be brief and conspicuous. A typewritten notice in an obscure corner is of no avail. Short, common words, and an unstilted style, so that the men will not only understand the notice, but be impressed by it, should be used in writing notices. It is better to state: "If you disregard this precaution you *will* be injured," than, "you *may* be injured."

However, notices are by no means sufficient, and no manager should rest serene with a mere posting of them. Constant instruction is necessary by word of mouth to all employees, not only at the time of employment, but constantly, as to all general hazards and those special ones to which their particular work is subject.

Booklets describing all hazards and giving instructions for their avoidance, explaining precautions against occupational diseases possible in the plant, and discussing general sanitation both in and out of the plant, describing accidents that have occurred in the plant or in similar ones, and explaining how they might have been avoided may well be distributed to all employees. The booklets should be printed in the language of the recipient. Publications of the American Museum of Safety, of the National Founders' Association,[a] and of some of the metal-trades associations on the points mentioned might also be distributed.

A most efficacious method is now and then to place a personal letter, or a special notice or bulletin pertaining only to the hazards of the recipient's particular work, in his pay envelope.

A "safety" bulletin board on which are displayed besides the usual notices, clippings from articles on safety which deal with the foundry, curves showing the ratio of accidents to men employed in the various departments during the past week, so placed that all workers have to pass it on the way to work, is used in several plants. The author chanced to visit one of these just after some new curves and clippings had been posted, and watched to see whether the workmen who passed it glanced at it or not. Out of half a dozen men who went by it while it was watched, not one failed to pause and read what was posted there.

GENERAL MEANS OF PROMOTING SAFETY.

Each man in the employ of a plant should be made to realize that the motto of the plant is "Safety first," and that it is his individual duty to look out for the health and safety, not only of himself, but of his fellow workmen. Careless employees should be kindly warned, and habitually careless ones should be discharged.

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[a] See editorial article, Foundry, vol. 42, 1914, p. 49.

Suggestions from the workmen for the guarding of hazardous places, or for safer methods, should be invited and used.

It is well to have weekly meetings of the foremen at which accidents or narrow escapes that have occurred are discussed and plans are made for the prevention of similar accidents. A lecture on sanitation, occupational diseases, and methods of giving first aid to the injured should be given each year to the foremen by a good physician.

There should be a safety committee whose duty it is to make a tour of the plant each week to inspect all hazardous places and to investigate occupational diseases and sanitation. This committee should take suggestions from any source from which it can get them and should report on all accidents or narrow escapes. The membership may include the plant manager, superintendent, some of the foremen, and one or two of the older workmen.

WELFARE WORK.

Whether a firm need go beyond the elimination of occupational diseases, the reduction of hazards, and the maintenance of sanitary conditions, into what is commonly termed "welfare work" will not be discussed here. There are, however, certain projects for the bettering of housing conditions, public baths, establishment of libraries, public parks, band concerts, etc., that are properly municipal affairs, but so vitally affect the physical and mental well-being of the employee in his life outside the factory gates that they may often be properly supported by the members of the firm, or, in some instances, receive subscriptions from company funds. The sanitation, water supply, and transportation facilities of the parts of the city or town affecting the employees of the company should be subject to scrutiny by its officials, and all proper steps should be taken to improve them.

SUMMARY OF ESSENTIALS FOR HEALTH AND SAFETY.

The employees of the modern brass foundry ought to find that the shop in which they work is properly lighted, heated, and ventilated and provided with pure water; that proper toilet and bathing facilities are provided and company time allowed for their use; that dust and fumes are so eliminated that the hazard of occupational disease is not present; that all machinery or appliances, such as saws, emery wheels, and sand blasts, are properly safeguarded; that the hours of labor and its character are reasonable; that medical attention is available, and that the motto of the foundry in word and spirit is "Safety first."

With such conditions there is no reason why the brass industry need be dangerous to health and safety, and as the worker's efficiency is dependent on his vitality, there is not one of the items named that will not pay the employer in dollars and cents.

ACKNOWLEDGMENTS.

It is a matter of regret that the necessity of obtaining the data for this bulletin in confidence prevents the specific acknowledgment of the aid of all who have so freely and so courteously supplied the information used in its preparation and have thrown open their plants for inspection. Especial thanks are due to the officers and members of the American Institute of Metals for their cordial cooperation, both personal and official, and to Prof. W. D. Bancroft of Cornell University, whose cooperation and advice have been both a service and an inspiration.

PUBLICATIONS ON MINERAL TECHNOLOGY.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp.

BULLETIN 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp., 6 figs.

BULLETIN 16. The uses of peat for fuel and other purposes, by C. A. Davis. 1911. 214 pp., 1 pl., 1 fig.

BULLETIN 19. Physical and chemical properties of the petroleums of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the Southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs.

BULLETIN 22. Analyses of coals in the United States, with descriptions of mine and field samples collected between July 1, 1904, and June 30 1910, by N. W. Lord, with chapters by J. A. Holmes, F. M. Stanton, A. C. Fieldner, and Samuel Sanford. 1913. 1200 pp (in two parts).

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 47. Notes on mineral wastes, by C. L. Parsons. 1912. 44 pp.

BULLETIN 53. Mining and treatment of feldspar and kaolin in the southern Appalachian region, by A. S. Watts. 1913. 170 pp., 16 pls., 12 figs.

BULLETIN 64. The titaniferous iron ores of the United States, their composition and economic value, by J. T. Singewald, jr. 1913. 145 pp., 16 pls., 3 figs.

BULLETIN 65. Oil and gas wells through workable coal beds; papers and discussions, by G. S. Rice, O. P. Hood, and others. 1913. 101 pp., 1 pl., 11 figs.

BULLETIN 70. A preliminary report on uranium, radium, and vanadium, by R. B. Moore and K. L. Kithil. 1913. 101 pp., 4 pls., 2 figs.

BULLETIN 71. Fuller's earth, by C. L. Parsons. 1913. 38 pp.

TECHNICAL PAPER 1. The sampling of coal in the mine, by J. A. Holmes. 1911. 18 pp., 1 fig.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 8. Methods of analyzing coal and coke, by F. M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 figs.

TECHNICAL PAPER 14. Apparatus for gas-analysis laboratories at coal mines, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 7 figs.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells, as practiced in California, by Ralph Arnold and V. R. Garfias. 1912. 12 pp., 1 fig.

TECHNICAL PAPER 38. Wastes in the production and utilization of natural gas, and means for their prevention, by Ralph Arnold and F. G. Clapp. 1913. 29 pp.

Technical Paper 39. The inflammable gases in mine air, by G. A. Burrell and F. M. Seibert. 24 pp., 2 figs.

Technical Paper 41. Mining and treatment of lead and zinc ores in the Joplin district, Missouri, a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs.

Technical Paper 43. The influence of inert gases on inflammable gaseous mixtures, by J. K. Clement. 1913. 24 pp., 1 pl., 8 figs.

Technical Paper 50. Metallurgical coke, by A. W. Belden. 1913. 48 pp., 1 pl., 23 figs.

Technical Paper 54. Errors in gas analysis due to assuming that the molecular volumes of all gases are alike, by G. A. Burrell and F. M. Seibert. 1913. 16 pp.

Technical Paper 60. The approximate melting points of some commercial copper alloys, by H. W. Gillett and A. B. Norton. 1913. 10 pp., 1 fig.

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